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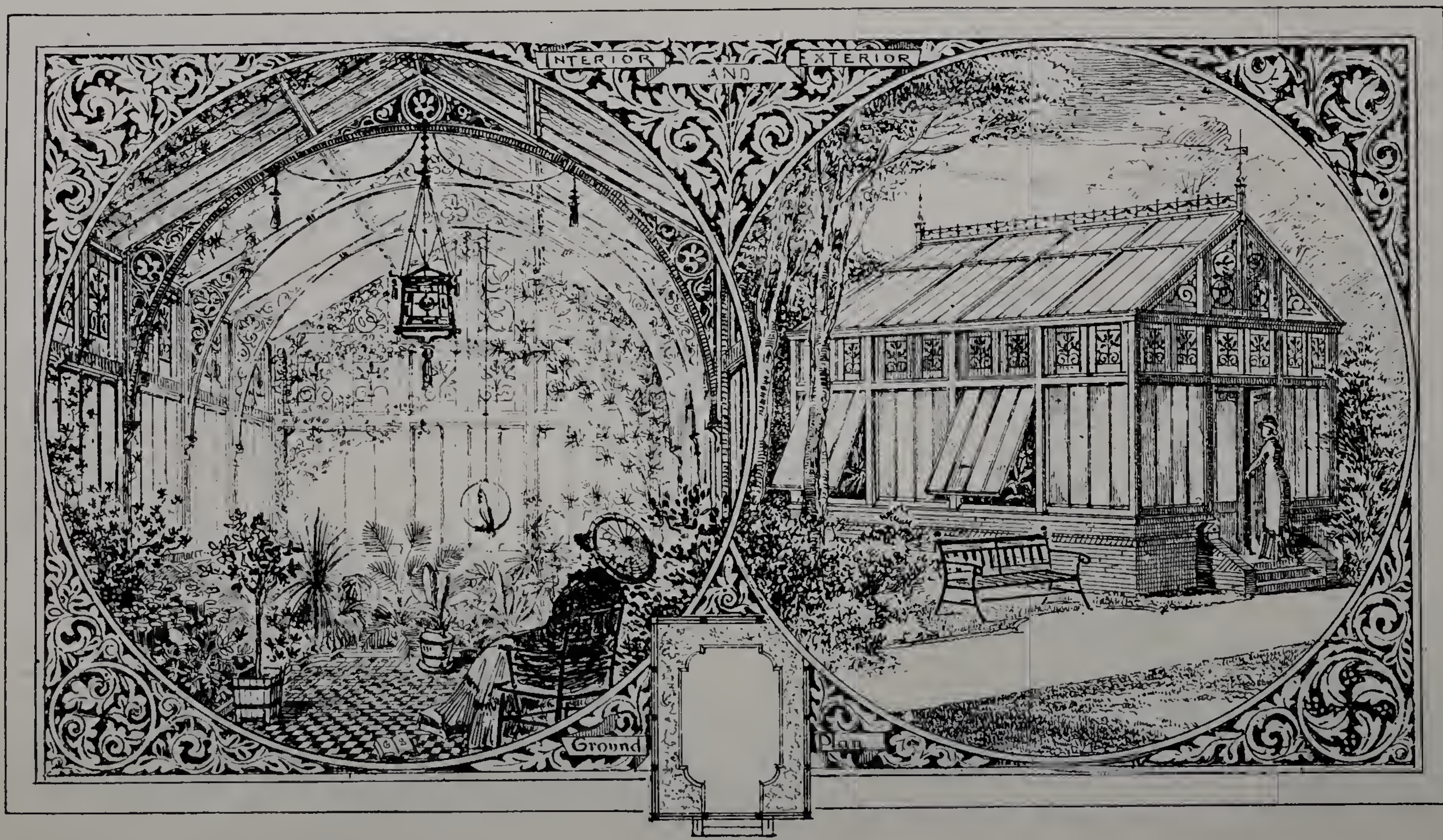
From Mr. CHARLES PENNY, Head Gardener to H.R.H. the Prince of Wales. The Gardens, Sandringham, 28th February, 1883:—"I must say your Fibre Refuse is far superior to any I have ever tried; in fact, it is simply perfection, and the use of your Fibre for so many purposes in Horticulture is a thorough boon. Make what use you like of this letter."

From *Gardeners' Magazine*, Sept., 1880:—"Messrs. Chubb, Round, & Co.'s Patent Cocoa-Nut Fibre Refuse is considered the best material for the formation of a plunge bed, as it most effectually protects the roots of the plants from an excess of heat or cold, prevents the worms entering the pots, and when plants are placed out of doors for the summer season much labour in watering may be saved, and injury to the plants prevented, by plunging the pots to within an inch or so of the rim in a bed of the 'Refuse.' In the case of those remaining out of doors during the winter, splitting the pots by frost, and the consequent injury to the roots may be effectually prevented by the same means. For beds for Hyacinths, Tulips, and other Bulbs, during the time the formation of new roots is in progress, the 'Refuse' is decidedly preferable to ashes or leaf mould, owing to its being much cleaner than either, and not likely to harbour slugs or other pests. A proportion of about one-third of the 'Refuse' to two-thirds of ordinary garden soil, will render it most suitable for Bulbs of all kinds, as it will keep the compost open, and enable the roots to run as freely as in the finest turfy loam. It is also useful for incorporating with heavy soils, more especially when devoted to the growth of flowering plants; whilst for mulching beds and

A. E. Smith.
July 4th 1887.


INTERIOR AND EXTERIOR
Ground Plan

HORTICULTURAL BUILDINGS.

Their Construction, Heating, Interior Fittings, &c., with remarks on some of the principles involved and their application.

(123 Illustrations.)

By F. A. FAWKES.

LONDON:

B. T. BATSFORD, 52, High Holborn.

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PREFACE.

MY position as member of the firm of T. H. P. Dennis & Co. of London and Chelmsford, has afforded me, during several years past, peculiar facilities for collecting practical notes on horticultural buildings; which notes appear, for the first time, in this volume. But in order that the public may derive every benefit from my experience, without any of the obvious disadvantages arising from my position, I have honestly endeavoured to treat the subject from an independent, disinterested stand-point. I have also endeavoured to ascertain some of the principles which underlie the mechanical details connected with horticultural buildings, and to embody a record of these principles in the notes.

The contents of this volume must be considered suggestive rather than exhaustive.

Up to the present date no book has existed, from which a gentleman could obtain, in a complete, concise form, unbiassed, reliable information to assist him in deciding what garden-structures would best suit his requirements: in which an architect could see just those constructional and mechanical points which should be decided by the horticulturist: and in which a gardener could find details beyond his province, but with which he should certainly be acquainted. There is frequently a natural repugnance, on the part of those who seek guidance, to consult horticultural builders' catalogues, which give no scientific, and very little practical information, and are necessarily regarded as trade advertisements.

The mechanics of horticulture has decidedly failed to receive that attention from the architectural and horticultural press, which the importance of the subject has warranted. While a vast amount of knowledge regarding plants, flowers, and fruit has been disseminated weekly, but little has been written upon the proper construction and arrangement of buildings required for the cultivation of those plants, flowers, and fruits.

If the present volume renders the gentleman, the architect or the gardener any assistance, and supplies a necessary link between the architectural and horticultural interests: if the architectural or horticultural press is stimulated to a more extended development of its functions: and if, by a combination of these results, horticulture is benefitted to the slightest extent, the objects I have in view will be attained.

My thanks are due to those firms and gentlemen mentioned in various parts of the book who have so kindly placed information at my disposal, and allowed me, for my own purposes, to illustrate their productions.

F. A. FAWKES.

Mansion House Buildings, London, March, 1881.

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INTRODUCTORY REMARKS.

IT may be considered that space is wasted in discussing elementary points of astronomy, meteorology, the solar rays, &c., in connection with the erection of glass-houses. It will be found, however, not only that some of the physical sciences form an integral portion of the mechanics of horticulture, but that without a knowledge of some of the laws of God, it is impossible to properly build and fit up such an apparently simple structure as a glass-house. When once correct principles are known, an application of those principles becomes comparatively easy.

THE METHOD.

The system adopted in this volume has been determined with regard to clearness and ease in reference. The work is divided into "articles" and subdivided into "sections." Headings indicating both will usually be found at the tops of the pages.

It will be noticed that, after general remarks, some of the elementary principles of astronomy and the sun's rays are introduced. Their bearing on glass roofs, aspect, site, &c., discussed. General hints on growing houses of all descriptions, conservatories, combinations of houses and subsidiary buildings included. Details of the various parts of houses, interior fittings, necessary adjuncts, &c., added. Notes on the general principles of heating, the apparatus, and its parts, brought prominently forward. Finally, some information regarding meteorological instruments, legal points and insurance appended.

Illustrations and tables are given where necessary. A copious index, analysis of contents, list of tables, and list of illustrations, all bearing the proper pagination, are annexed to the subject matter. Additional value is imparted to many of the diagrams and sections by engraving them to a given scale (such as $\frac{1}{8}$th or $\frac{1}{16}$th inch to a foot), instead of merely having an arbitrary scale line shown upon them, as is usual. This has been easily and accurately effected by photographing the author's sketches on to the wood blocks by a process discovered by Mr. Arthur E. Smith. By this mode there is no collodion film to "scale" under the graving tool. So that an artist need not draw upon the blocks himself, but may be certain of having his work reproduced on the wood to any reduced or enlarged scale, without involving an intervening process of hand-copying with its attendant disadvantages.

For the sake of perspicuity, technicalities are avoided as much as possible. In all remarks, the word "house" or "houses" refers to horticultural buildings. Dwelling houses are not meant unless so specified.

Any information, bearing even indirectly upon mechanical construction, is included; but anything having reference to the cultivation of plants is omitted, as it is not thought desirable, in the present volume, to trespass upon the province of the gardener proper.

It may sometimes be noticed that the same information is given more than once. This, however, is only the case when mere cross references are undesirable. Different articles and sections necessarily overlap one another, and such overlapping is frequently found advantageous.

GENERAL HINTS FOR AMATEURS.

The following notes may be useful to amateurs and others, who, perhaps for the first time in their lives, contemplate the cultivation of plants under glass.

First of all, have a clear idea what and how much you wish to grow. This advice applies equally whether you own a large establishment, or are tenant of a small semi-detached suburban villa. Strange as it may seem, this point is most frequently lost sight of altogether. Whether it is a problem which requires some little trouble and thought to work out, or whether it is considered that other and more easily-defined limits are preferable, is immaterial, for certainly, although it should form the first question, it is too often allowed to merge into the next question—"What is the limit of money which it is desirable to expend upon the proposed buildings?" Then is there a danger that a mistake of an important character will be made by the question resolving itself into "What is the maximum space I can cover for a fixed or a minimum sum?" If once this idea is carried out, a liberal crop of error is sown, which will inevitably result in reaping an extensive harvest of trouble. If you have no other way of limiting your proposed horticultural buildings than a monetary one, by all means use it, but do not abuse it. On the other hand, do not let your ideas be too extensive for your pocket, either as regards first cost or working expenses. If you formulate your plans and they prove too costly, cut them down in dimensions rather than efficiency. What is worth doing at all is worth doing well, and a house thirty feet long, properly constructed and efficiently worked, is far preferable to a corresponding house, double the length, costing the same sum, but scamped in construction and only receiving half the necessary subsequent attention.

Having say, only a hazy idea of what you want to grow, make yourself master of all the facts of the case. Investigate the local and incidental circumstances, such as aspect, situation, soil, drainage, best description of building or buildings for the purposes required, most suitable dimensions, heating apparatus, interior fittings, as well as all the attendant conditions which go to determine what you will build. Act as if you were putting together a child's puzzle, so that all the pieces may finally dovetail harmoniously. By all means consult your gardener. Remember that he will have to use the proposed glass work, and will probably not only have a keen notion of what will best suit the desired purposes, but will take greater interest in structures, in the planning of which he has had a voice. At the same time, beware of crotchets. Gardeners are only human.

So far these remarks will apply chiefly to growing-houses. If the contemplated building or buildings are destined for showing plants rather than growing them, then the mind must be concentrated upon points of architecture and art, decoration, and fittings, upon the beautiful in mechanics and materials, which will harmonise with the beautiful in nature. Reference should be made to the article on "Show-houses," in which this phase of the subject is treated in detail.

HISTORICAL.

The artificial treatment of plants, which has culminated in the latest improvements connected with horticultural buildings, may be divided into three distinct stages. The first was clearly the desire to protect, during the winter, pleasing and delicate evergreens from frost. Following this, in natural sequence, came the desire to perfect the means for the acclimatization of plants, &c., not indigenous to our soil and climate. Then, later still, came the wish to anticipate, by artificial means, the natural ripening and blooming seasons of fruits and flowers.

The first stage gave mere protection, in which glass played a very unimportant part, the walls being formed of brick or stone with windows at intervals, which formed the only means for admitting light.

The second stage gave us buildings in which the walls had a little more window space in them, a certain proportion of the roof was glazed and some means were used for artificial heating, either by putting a stove in the building (hence the term "stove,"—building in which a stove is placed), or by placing burning embers in a receptacle underneath the building (hence the old term for a stove, "hypocaustum"—from Greek words meaning "under" and "to burn").

The third stage gave us forcing-houses proper—minimum obstruction to the rays of light by the maximum amount of glass in the roof and sides; means for the delicate manipulation of heat, light, and ventilation; and various appliances, such as plunging beds with bottom as well as atmospheric heat, &c., &c.

The commercial results of the discovery of America and of the passage to India by the Cape of Good Hope gave an impetus to gardening, and it became necessary to erect green-houses for the shelter and cultivation of the rich and rare fruits and flowers received from tropical countries.

The Chinese have for some time been acquainted with green-houses, but how far back their knowledge extends is not known.

According to Mr. Loudon, the first green-house of which we have any record was erected about 1619 at Heidelburg, by Solomon de Caus, architect and engineer to the Elector Palatine. This green-house was originally constructed to shelter orange trees. Between this time and the end of the 17th century, myrtles, sweet bays and heaths, as well as the orange tribe, were sheltered by houses having windows only on one or more perpendicular sides; for such purposes a large amount of light was not then considered advisable.

A green-house in the Apothecaries' garden at Chelsea was mentioned by Ray in 1684. It was not, however, till about the beginning of the 18th century that the desirability became apparent of rendering a large amount of the sun's rays available, and glazed roofs became at all general.

The following précis of instructions given in the Encyclopædia Britannica published in 1810, for the construction of a conservatory or green-house, may be considered amusing at the present date:—

> "No glass roof, but a seed-room over. Cornice about 18in. deep. "Lower brickwork about 18in. high. Piers of masonry 2ft. 6in. thick "in front and 18in. thick at back. At every 7ft., intermediate masonry "about 7ft. high filled in by glass work and shutters to fold behind "them. Floor raised 2 to 3 feet above adjoining ground, tressels of "wood inside with forms upon them as stages."

When the duty was taken off glass, horticultural buildings, which before were a decided luxury, now became almost a necessity.

So far as can be gathered, the first artificial heat employed in houses in England, was obtained by placing burning embers in holes in the floor. The antiquity of hot-water heating is beyond a doubt, for Castell, in his "Illustrations of the Villas of the Ancients," gives us drawings of the mode of heating the Thermæ of Rome, as described by Seneca. By these we see that the baths were heated by passing the water through a coil of brass pipes in the fire. Thus, before the Christian era, the same principles were applied, by which, at the present day, we carry out hot-water heating.

SOCIAL.

The social advantages of a green-house are great. We know that "contact with, and a proper contemplation of, God's works, has a refining influence on mankind," so that a due appreciation of a garden will be morally elevating. A green-house enables both the contact and contemplation to be intensified, therefore a person cannot but be ennobled who thoroughly appreciates and properly uses a green-house. To watch in a glass-house the growth of a pretty little helpless plant, to promote its development amidst adverse external circumstances, to shield it from cold, to protect it from the sun's scorching rays, to deliver it from its insect persecutors, to feed it, all these go far to touch in the human mind a mysterious chord of sympathy for the little plant, to soften the temper, and to establish a fascination which is equally powerful to the aged couple who are approaching their golden wedding day, to the happy bridal pair in their new home, or to the grandchild of twelve summers.

Fruit, as well as flowers, are doubly valuable, and they have to us a very peculiar flavour (which the most educated palate of a connoisseur would fail to detect) if they are produced under our own care, and in our own hot-house. Pleasure and fascination are increased if we take our microscope into our green-house, go deeper into the mysteries of plant life, and examine the exquisite beauty, order, and method in the hitherto invisible. The wonderful epidermis and stomates of pelargoniums, scalariform ducts of ferns, spiral vessels of roses, pollen, the numerous insects which find their whole world on a plant, and the thousands of strange phases of organic life revealed by the microscope, will afford food for delight and reflection during many spare hours. A pessimist will be transformed into an optimist when he sees that the world is no longer a "barren and howling wilderness," but replete with unthought-of beauties. Our green-house will thus become a reservoir of interest and information, in fact, a scientific kaleidoscope, having an almost inexhaustible series of delightful combinations.

Although the more extensive the horticultural buildings, the greater will be the tangible results which may be obtained from them, let it not be supposed that therefore the greater will be the pleasure derived. It not unfrequently happens, on the contrary, that the pleasure is in inverse proportion to the size of the buildings, and that the happiness experienced by one person, of enjoying, for the first time, the luxury of a little green-house only a few feet square, is infinitely greater than the interest taken by another person in an extensive range of hot-houses, requiring the attention of several men, and producing fruit and flowers, of every description, all the year round.

If a contemplation of the beautiful, the good, and the true has a refining influence, then, apart from plant life, we should strive, to the utmost extent of our ability, to render our conservatory a thing of beauty, and, therefore, a joy for ever. The judicious selection and disposition of plants and flowers, a chair or two, a curtain, and a little old china, may turn a conventional conservatory into an artistic floral reception room. There can be little doubt that philosophers are right when they say that every man should not only exist and live, but should have means for recreation and rest apart from sleep. A conservatory properly built, and thoughtfully and artistically furnished, affords an excellent opportunity for healthful rest and recreation.

Upon social, hygienic, moral, and even religious grounds, horticultural buildings may justly claim advantages of a solid and superior character.

ASTRONOMICAL.

IN discussing green-house arrangements, our first difficulty is with the seasons. So long as we have winter and summer, cold and warmth, long and short days, it is much more satisfactory to talk about our green-houses and conservatories after we have a clear notion of some of the reasons for these various changes.

We experience cold in winter and heat in summer, not because we are nearer the sun in summer than in winter (in point of fact we are nearest the sun about January 1, and farthest about July 1), but by reason of the "inclination of the earth's axis to the plane of the ecliptic." This will be clear from the following :—For the sake of argument we will suppose that the earth spins round on its axis A B (Fig. 1), and that C D is the plane of the ecliptic (earth's orbit or path round the sun), also that E F, the equator, is coincident with this ecliptic. It is obvious that, to a spectator

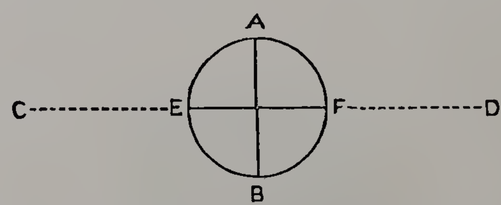


FIG. 1.—The earth's axis at right angles to the plane of the ecliptic.

on any part of the circumference E F, the sun would seem to describe a complete semi-circle in the heavens, rising due east, passing across the zenith and setting due west. To such a spectator this semi-circle would never vary. Similarly, the apparent path traversed by the sun, to a spectator on any other part of our globe, would never vary. Now, inasmuch as the relative position of the earth and sun is not as shown by Fig. 1, but as shown by Fig. 2, in which the axis A B of the earth is inclined

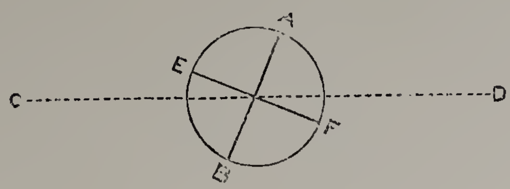


FIG. 2.—The earth's axis inclined to the plane of the ecliptic.

about 23° 28′ to the plane of its orbit C D (E F being the plane of the equator), it follows that the apparent path of the sun to a spectator varies throughout the year.

The sun's declination is the angular distance between the equatorial plane and the ecliptic. As the planes C D and E F in Fig. 2, where they touch the earth, both represent circles on the earth's surface, it will be seen that these two circles intersect each other at two points which are called the equinoxes (from *æquus*, equal, and *nox*, night). One is called the vernal equinox (March 21st), and the other the autumnal equinox

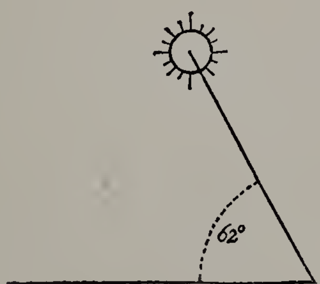


FIG. 3.—Angle of sun's maximum altitude during the longest day.

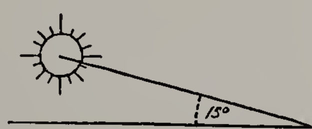


FIG. 4.—Angle of sun's maximum altitude during the shortest day.

(September 23rd). When the sun reaches his furthest point, north of the equator, it is called the summer solstice. This occurs June 21st, and is, of course, the day on which the sun is the greatest length of time above our horizon. When the sun reaches his lowest point south of the equator, it is called the winter solstice. This occurs December 21st, when the sun remains the shortest time above the horizon. The maximum height the sun attains at the summer solstice is about 62° (61° 57′ 15″), and at the winter solstice about 15° (15° 2′ 45″) above the southern horizon. These angles are represented in Figs. 3 and 4. Here we have one of the reasons for our climatic changes. For, supposing a pencil of solar rays (these are practically parallel) to strike a flat surface when directed at the angle shown in Figs. 3 and 5, and another pencil of rays, of the same diameter, to strike the surface at the angle shown in Figs. 4 and 6, it is obvious that the latter will cover a much larger area than the

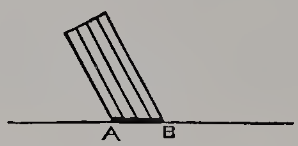


Fig. 5.—Maximum inclination of pencil of solar rays during the longest day.

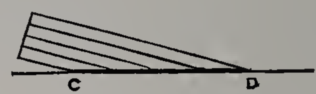


Fig. 6.—Maximum inclination of pencil of solar rays during the shortest day.

former. The rays, therefore, falling on A B, Fig. 5 (other things being equal) will feel much warmer than the rays on C D, Fig. 6. It is clear that if the obliquity of rays were increased until the surface was in the same plane as the rays, the surface would cease to receive the rays at all. The rule is, that "the intensity diminishes in the same proportion as the "sine of the angle of obliquity of such surface to the direction of the rays "is diminished."

Again, this inclination of the earth's axis to the plane of the ecliptic, as is evident from Fig. 2, causes the relative lengths of day and night to vary, so that, in addition to the rays being weaker in winter, the sun does not shine each day for so long a time as in summer. In short, the earth is not heated so much nor so long, and has a longer time to get cool by radiation in winter than in summer.

Again, it is self-obvious that when the sun's rays shine, as shown in Fig. 4, they are more refracted and pass through denser vapours, thus rendering them additionally weaker than when they shine as in Fig. 3.

It is needless to discuss the interesting climatic and other changes which may be effected by placing an imaginary spectator at different spots on our earth's surface. For practical purposes it will be sufficient to remember that, say in London on the longest day, June 21, the sun rises about 50° (50° 15′ 20″) east of north, attains a height of 62° above the horizon and sets about 50° (50° 15′ 20″) west of north, remaining above the horizon about 17 hours; and that on the shortest day, December 21, it rises about 50° (50° 15′ 20″) east of south, attains a height of about 15° above the horizon, and sets about 50° (50° 15′ 20″) west of south, remaining above the horizon about 7 hours. (See Figs. 7 and 8.)

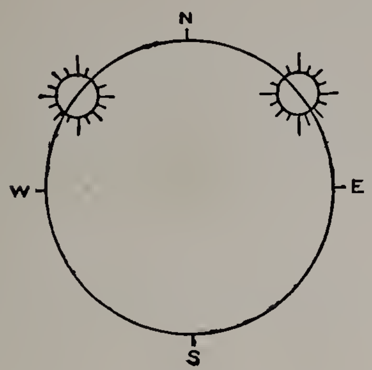


Fig. 7.—Points on the horizon of the sun's rising and setting on the longest day.

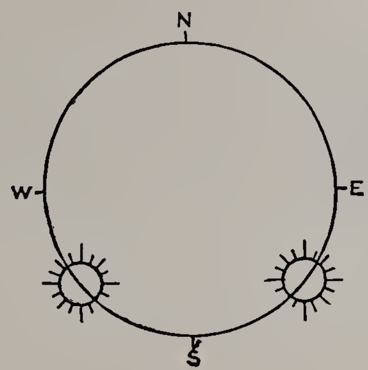


Fig. 8.—Points on the horizon of the sun's rising and setting on the shortest day.

In this way the reason of the seasons will, it is hoped, be rendered sufficiently clear for practical purposes. It only remains to say that the term "latitude" means the angular distance of any place on the globe, north or south of the equator (in the case of England any latitude indicated would of course be north), and to intimate that under the articles, "Sun's Rays," "Aspect," "Inclination of Roofs," some of the few astronomical facts mentioned here are again touched upon for the purpose of more clearly explaining the points raised.

THE SUN'S RAYS.

PLANT LIFE.

AS the life of plants, under glass as well as in the open air, so essentially connects itself with the sun's rays, a glance at the scientific properties and treatment of those rays, even at the risk of stating some facts patent to everyone, will be found advantageous.

Vegetable carbon owes its origin to the atmospheric carbonic acid. By the chemical action of the sun's rays, the carbon is set free from the oxygen; the former assimilates the elements of water, forming cellulose or woody fibre; the latter returns to the atmosphere in the gaseous form.

The solar rays may be said to possess three distinct powers,—lighting, heating, and producing chemical action. So distinct are these powers, that we can separate the heat rays from the light rays, and partially or wholly stop either at will. The rays producing chemical action can also be examined, in a great measure, apart from the heat or light rays.

LIGHT RAYS.

A ray of light may be partially or wholly stopped in several ways. It may be turned from its path by reflection or by refraction. It may be swallowed up, so to speak, by absorption. Or its obstruction may ensue from a combination of these causes. Light, passing through a vacuum, is transmitted without any loss; but whenever it traverses any medium, however transparent, some of it is stopped. In fact a certain depth might be assigned to the atmosphere, which would completely intercept the solar light. About 7 feet of water is sufficient to intercept half the light of a ray passing through it. According to Dr. Letheby, the loss of gas light in its transmission through gas globes is as follows :—

Table I.—Loss of Light by Transmission through Glass.

Gas Globe of Clear Glass	Loss 12 per Cent.
,, ,, Ground ,,	,, 40 ,,
,, ,, Opal ,,	,, 60 ,,

But if light only reached us by the direct rays of the sun, then at noon-day, an opaque body, interposed between our eyes and the sun, would simply have the effect of giving us an instantaneous midnight. That this is not so, and that during the daytime we see light everywhere, although we may not absolutely see the sun, is due to the fact that light is reflected or diffused, from all bodies.

Table II.—Loss of Light by Reflection from Glass.

Angle made by Sun's Rays with Glass.	Rays Impinging.	Rays Lost by Reflection.
5°	1,000	543
10°	1,000	412
15°	1,000	300
20°	1,000	222
30°	1,000	112
40°	1,000	57
50°	1,000	34
60°	1,000	27
70° to 90°	1,000	25

A very important fact regarding direct rays of light, which has a bearing on the subject of green-houses is this. That the proportion of light rays lost by reflection from such a surface as a smooth plate of transparent glass, varies with the angle at which the rays impinge upon the medium. This is strikingly shown in Table II. (p. 13), given by Bouguer.

If, therefore, we wish to utilize the greatest proportion of the direct solar light rays, when transmitting them through glass, it will be obviously our most advantageous course to arrange that the rays shall strike such glass at as nearly a right angle as possible. (See "Inclination of Roofs.")

In consequence of the great distance of the earth from the sun, the solar rays may practically be regarded as parallel with each other when they strike the earth. When the luminous point is near at hand, the rays must necessarily be considered divergent. The law of divergent rays is that their intensity decreases inversely as the square of the distance from the luminous point. This is very clearly shown by Fig. 9, a reproduction of an illustration in that excellent little book, "Philosophy in Sport."

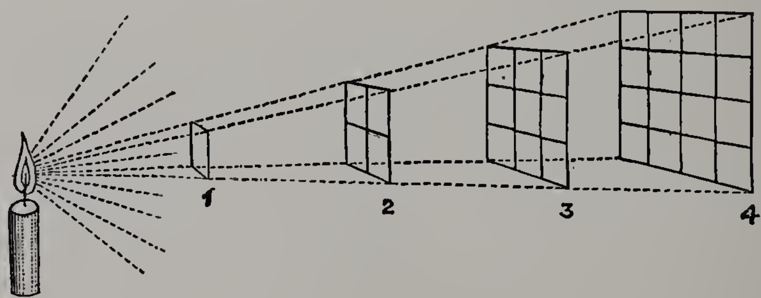


FIG. 9.—Diagram illustrating law of radiant light and heat.

If a screen, say 1 square foot in area, be held at a yard distant from a candle, the area shaded by those rays at 2 yards would not be 2 but 4 square feet; at 3 yards, not 3 but 9 square feet; at 4 yards, not 4 but 16 square feet. In other words, the same rays which, at 1 yard distant, would give a certain intensity of illumination, at 2 yards would give, not $\frac{1}{2}$ but $\frac{1}{4}$ the intensity; at 3 yards, not $\frac{1}{3}$ but $\frac{1}{9}$ the intensity; at 4 yards, not $\frac{1}{4}$ but $\frac{1}{16}$ the intensity; and so on.

HEAT RAYS.

The solar heat rays are subject to the same phenomena of partial or entire interception by reflection, refraction, and absorption as the light rays, but the same substances have not the same effect on both. This is exemplified by interposing a plate of glass between a bright fire and the face. The heat rays are perceptibly intercepted, the light rays are not. Solar heat rays, like light rays, are transmitted through a vacuum without loss. Through an elastic fluid such as the atmosphere, they are transmitted with very little loss, but when that distance is greatly increased, interception is much facilitated. This affords one good reason why the morning or evening rays are much less powerful than the noonday rays. But heat is transmitted in other ways than by radiation—viz., by conduction and convection. When two substances are placed in contact, one hotter than the other, the former conducts or transmits to the latter a portion of its heat till both are in equilibrium. Treated in this way, quiescent dry atmospheric air is one of the worst conductors of heat. By convection is understood the process of conveying heat by currents. Convection takes place when heat is applied beneath a vessel of water, and currents conduct the heat from one part to another. Thus, although quiescent air may be a bad conductor, set it in motion, and it becomes a good transmitter of heat by convection.

The law given in the previous section, that the intensity of divergent rays decreases inversely as the square of the distance from the luminous point, applies to heat as well as light rays.

Additional data and remarks more nearly connected with artificial heat and its application are given in the article on heating.

CHEMICAL RAYS.

Besides the rays of light and heat, we have the actinic (chemically active or photographic) rays. Although a portion of these rays is incorporated with the light rays, still a certain portion is perfectly invisible. As will be seen by the annexed table of the results of experiments by Drs.

Roscoe and Thorp, the intensity of these actinic or chemical rays varies with the altitude of the sun.

TABLE III.—ACTINIC INTENSITY OF DAYLIGHT.

Mean Altitude of Sun.	Chemical Intensity.		
° ′	Sun.	Sky.	Total.
9 51	0	38	38
19 14	23	63	86
31 14	52	100	152
42 13	100	115	215
53 9	136	126	262
61 8	195	132	327
64 14	221	138	359

These experiments were made at Lisbon, where the sun attains a higher altitude than in England. It will thus be seen from this table, and from the preceding remarks, that at altitudes below 10° above the horizon, direct sunlight is robbed of all its chemical rays, and that the nearer the sun sinks towards the horizon the less intense are its heat, light, and actinic rays. From numerous simultaneous experiments carried out by the same gentlemen, it was ascertained that the average of the chemical intensity of daylight at Para was 303·2, Lisbon 110, and Kew 46·06; or more than 6½ times greater at Para than Kew. These figures are of value, as representing, for botanical purposes, the relative chemical activity of daylight in England and the Tropics.

Although we can examine the actinic rays almost apart from the light and heat rays; can tell, by experiment, when they are strongest, when weakest; and can even determine that there are at least two descriptions of actinic rays (those which can commence but cannot continue chemical action, and those which can continue when started but cannot commence chemical action); yet our knowledge of the bearing of these rays on plant life is not yet sufficiently advanced to enable us to benefit materially in constructing our glass-houses. The day may come when we shall as easily regulate our actinic rays as we do our light and heat rays.

From this cursory glance at the sun's rays, we see that in constructing and using our green-houses, it is of immense mome nt that we have, not only a clear idea of the properties of those rays, but possess appliances, with the knowledge how to use them, for ensuring the transmission of the maximum amount of solar light and heat rays when necessary; of moderating their intensity when we wish; of intercepting either one or other as we may desire; of stopping all direct rays and utilizing only diffused rays when advisable; of producing, directing, and controlling an artificial supply. In point of fact, of turning on, adjusting, or shutting off our light and heat in accordance with our demands, with the same ease that we deal with the hot and cold water supply to our baths.

INCLINATION OF ROOFS.

THE proper inclination or pitch of the roofs of horticultural buildings is a very important point, and depends upon a combination of conditions. One very necessary condition is to insure the transmission of the sun's rays in the most complete manner, and at the time when they are most required.

We will first of all presume that every other condition is subordinate to this, and that we only have to determine the inclination which is the best adapted for growing, ripening and fruiting purposes, so far as relates to the sun.

ANGULAR MEASUREMENTS.

The pitch of a roof is the angle which is formed between the roof and a horizontal line drawn not lower than the eaves or the lowest point of the roof (see Fig. 10). If A C be the total height of vertical front, and B D the back wall, we draw a horizontal line through A. We then place a protractor on this horizontal line with the centre at the point A, when, if we require a roof of an inclination of 30° pitch, we draw the line A E intersecting the protractor at the point marked 30°. Or, if we require a roof of 40° pitch, we draw the line A F intersecting the protractor at the point marked 40°. It must be remembered that the horizontal line through A is the base line from which all the angles of roofs are taken, as if the back wall B D be taken as a base line, mistakes will of course occur. Any pitch of roof can thus be readily ascertained.

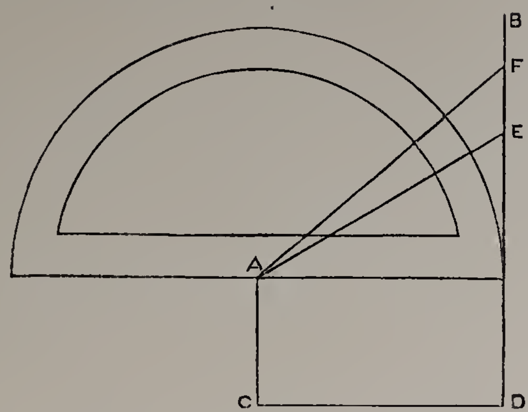


FIG. 10.—Method of determining angular measurement of roofs.

With a given height of back wall, and a given width of house, the pitch of roof will, of course, vary. Table V. will give the varying inclinations for different widths of houses and varying heights of back walls above vertical fronts. The spaces are left blank where it is considered that the pitch is too low for practical purposes. By vertical front, is of course meant the whole vertical height (generally composed of part brickwork and part glass work) before the "spring" of roof is reached.

The following table may be useful as showing the angle, which is equal to a rise of 6″ to 15″ in the foot:—

TABLE IV.—ANGULAR MEASUREMENT OF ROOFS.

Rise in Inches per Foot.	6″	7″	8″	9″	10″
Angle of Roof.	26° 33′	30° 15′	33° 41′	36° 52′	39° 48′
Rise in Inches per Foot.	11″	12″	13″	14″	15″
Angle of Roof.	43° 10′	45° 0′	47° 57′	49° 24′	51° 20′

TABLE V.—ANGULAR MEASUREMENT OF ROOFS.

Width of House in Feet.	Difference of Height between Back and Front Walls in Feet.																									
	3		4		5		6		7		8		9		10		11		12		13		14		15	
	°	′	°	′	°	′	°	′	°	′	°	′	°	′	°	′	°	′	°	′	°	′	°	′	°	′
6	26	33	33	41	39	48	45	0	49	24	53	8	56	18	59	2	61	24	63	27	65	13	66	48	68	12
7	23	12	29	44	35	32	40	36	45	0	48	49	52	7	55	0	57	32	59	45	61	42	63	26	65	0
8	20	33	26	33	32	0	36	52	41	11	45	0	48	22	51	20	53	58	56	19	58	24	60	16	61	56
9	...		23	57	29	3	33	5	37	52	41	38	45	0	48	0	50	43	53	8	55	18	57	16	59	2
10	...		21	48	26	33	30	58	35	0	38	39	41	59	45	0	47	44	50	12	52	26	54	27	56	19
11	...		...		24	26	28	36	32	28	36	2	39	17	42	16	45	0	46	50	49	46	51	51	53	45
12	...		...		22	57	26	33	30	15	33	41	36	52	39	48	43	10	45	0	47	57	49	24	51	20
13	...		...		21	2	24	47	28	18	31	36	34	42	37	34	40	14	42	3	45	0	47	7	49	5
14	...		...		...		23	12	26	34	29	44	32	44	35	39	38	9	40	36	42	53	45	0	47	0
15	...		...		...		21	48	25	1	28	4	30	58	33	41	36	15	38	40	40	55	43	0	45	0
16	...		...		...		...		23	38	26	33	29	21	32	0	34	0	36	52	39	5	41	11	43	9
17	...		...		...		...		22	21	25	12	27	54	30	28	32	54	35	13	37	24	39	28	41	25
18	...		...		...		...		21	15	23	57	26	33	29	3	31	26	33	5	35	50	37	52	39	48
19	...		...		...		...		...		22	50	25	21	27	46	30	4	32	16	34	23	36	23	38	17
20	...		...		...		...		...		21	48	24	14	26	30	28	49	30	58	33	0	35	0	36	51

BEST TRANSMISSION OF SOLAR RAYS.

From Bouguer's table (see the "Sun's Rays,") it will be seen that the more nearly do the solar rays form a right angle with glass, the less is light lost in transmission. It may, therefore, be necessary to construct a roof of such a pitch that the maximum amount of sun's rays shall be admitted at or about a certain date, when all the sun power which can be obtained is required for ripening or other purposes. Thus, supposing A B (Fig. 11) to represent a sheet of glass, taking the total rays of light inpinging as 1,000 ;—

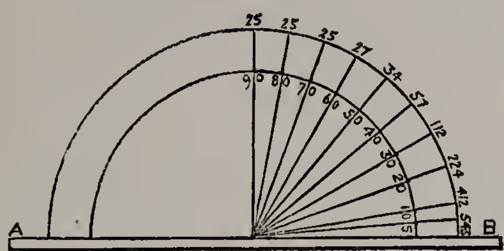


FIG. 11.—Loss of solar rays in transmission through glass.

The numbers near the outer semi-circle will show the rays lost by reflection, and those near the inner semi-circle, the angle of incidence. From this diagram we see that if the sun's rays strike the glass at any angle between 60° and 90°, only about 25 out of 1,000, or $2\frac{1}{2}$ per cent. of the sun's rays are lost. This allows us a range of 30° on each side of the perpendicular, with the minimum loss of rays. Now, if a glass roof be inclined so as to face the south at an angle equal to the latitude of the place, a greater amount of solar rays will pass through such roof at, say the equinoxes, than if it were inclined at any other angle.

But, according to the above diagram, we may safely deviate, at any rate, 20° on either side, so that if, when built at an angle of 51°, a roof receives the sun at an angle of 90°, we may incline our roof at any angle between 31° and 71° without materially affecting the amount of rays transmitted through it. This allows us a good margin for the consideration of other points in the determination of the pitch of our roofs.

If, however, we desire accuracy of the highest degree, and require that our glass roof shall, on any particular day in the year, receive the rays of the sun (when at its highest altitude) at a perfect right angle, we have only to take the latitude of the place, and from it subtract the sun's declination between the vernal and autumnal equinox, or to it add the sun's declination between the autumnal and vernal equinox, and we shall obtain the angle of inclination of the roof. This will be self-evident from the annexed figure :—

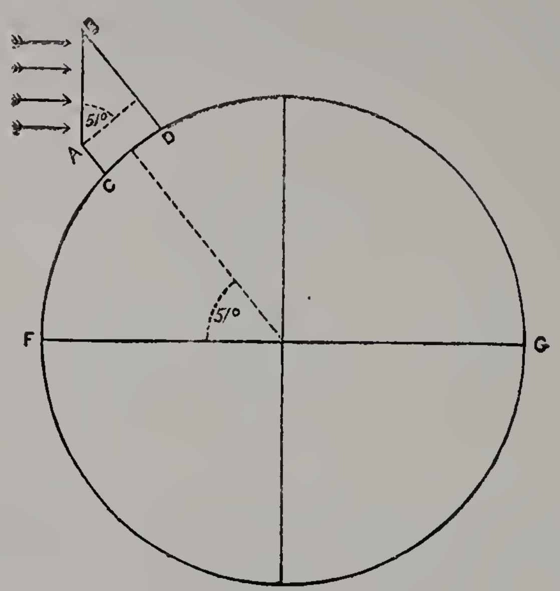


FIG. 12.—Relation between inclination of roof and latitude.

A B D C represents the section of a green-house built upon the earth at latitude 51° north. The roof A B is constructed with an inclination of 51° to the base line. The arrows show the rays of the sun striking the roof A B at right angles. The figure is drawn supposing the equator F G is coincident with the plane of the ecliptic. As the two planes intersect one another on March 21 and September 23, the figure would be correct for these two dates only (that is, at the two equinoxes).

Suppose, however, we wish to find in the same latitude, 51°, the angle of elevation which a roof should have, to receive, on say August 15th, the sun's rays at right angles to the glass. 51°, the latitude, minus 14°, the sun's declination on August 15, equals 37°, the angle of elevation of roof, Similarly, there is a variation of 1° in the pitch of roof for every corresponding variation in the latitude, so that, adhering to the same day, August 15, Table VI. will give us the inclination of roof for any latitude between the north of Scotland and the south of England.

TABLE VI.—PITCH OF ROOFS AT VARIOUS LATITUDES.

Latitude.	50°	51°	52°	53°	54°
Most favourable pitch of Roof.	36°	37°	38°	39°	40°
Latitude.	55°	56°	57°	58°	59°
Most favourable pitch of Roof.	41°	42°	43°	44°	45°

But August 15 is nearly eight weeks after the longest day, so that the sun's rays will also fall perpendicularly to the roof about April 27, or eight weeks before the longest day. With this arrangement the sun's rays would only deviate about 10° at Midsummer, a deviation which is, as explained previously, immaterial. The immediately preceding table may, therefore, be taken as indicating the most favourable pitch of roofs in various latitudes which can possibly be constructed.

VARIOUS CONDITIONS.

The foregoing remarks are intended to apply more particularly where but little artificial heat is used, or where sun-heat is required under the most favourable conditions. Where ample fire-heat is available, the pitch of roof may be allowed to depend more upon other conditions. These may be summarized as follows :—

Fixed height for back wall.

Fixed height for vertical front.

Fixed width of house.

Inclination of roof which shall suit construction best.

Influence of inclination of roof on heating.

Distance of roof from plants.

Inclination of roof in relation to condensation and drip.

If the height of an existing back wall cannot be altered, and the width of the house be determined by some local condition, we can yet vary the pitch of roof by raising or lowering the vertical front. Sometimes it is necessary to adhere to a definite height of front, to a definite width of house, and to preserve a back wall which is not high enough for the purpose of a desired inclination of roof. It will frequently be possible to overcome such a difficulty by giving the roof the required slope until a certain point is reached where, by dropping the roof at the same angle, the top of the low back wall is just reached (see Fig. 29). Of course, where it is necessary to have a continuous rafter, undisturbed by the break of a ridge, the space between the top of the roof and the top of the wall must be filled up by a vertical glass spandril.

A roof must not have an inclination which is entirely unsuited to constructional requirements. For instance, it is found by experience that if a glass roof have a lower pitch than about 26°, or 6″ rise in a foot, rain is apt to drift under the laps. Sometimes, especially in span-roof conservatories, a pitch of 30° is convenient, as a circular strengthening rib to rafters can be more easily introduced in a roof having 30° pitch than any other. (See "Show-houses.")

As will be seen elsewhere (see article on "Heating"), it is important that all the air in the interior of a hot-house should be heated as equally as possible, for the sap has a natural tendency, not only to flow to the highest part of plants, but to flow to the spot where the greatest heat exists, so that the higher the pitch of the roof, the greater the tendency for hot air to accumulate near the top of the house, and for the sap to rise to the higher parts of the vines, plants, &c., to the detriment of the lower parts. The lower the pitch of roof, consistent with the due admission of solar rays, the less probability of a difference of temperature between the upper and lower part of roof.

It is also desirable that the plants should not be grown too far from the surface of the glass, and due regard must be had to this point in determining the pitch of roof.

Again, the lower the pitch, the greater will be the likelihood of moisture condensing and dripping on the leaves. The higher the pitch, the longer the length of rafter available for vines, &c. The question of roofs in relation to drainage is discussed in another place (see "Drainage"), but it may be remarked that the weight of snow on a roof varies from 3 to 10 lbs. per foot super, according to climate.

The pitch of roof has also an influence upon construction, for if a roof be not properly "tied," a high or low pitch may greatly affect lateral thrust.

The pitch of roof may be required to deviate from an otherwise suitable inclination where wall-fruit only have to be preserved. (See "Wall-tree Protectors.")

It may be taken for granted, that where great heat is necessary, the plants require to be near the glass, and houses are built low, 26°, or 6″ in the foot, is a very good inclination of roof. Where the solar rays are important for ripening purposes, from 36° to 44°, in accordance with Table VI., p. 23. For general purposes, and as may be determined by other conditions, from 26° to 44°. And for a specially narrow, high form of house, such as a wall-tree cover, a greater pitch than this, if required.

Roofs with more than one pitch, and curvilinear roofs, are treated in other sections.

ASPECT AND SITE.

HORTICULTURAL buildings usually require to be so placed that they may receive the maximum amount of the sun's rays. The position of the sun (see "Astronomical") when it reaches every dayits maximum height, is somewhere between the southern point of the horizon and the zenith; in fact, between altitudes 15° and 62°. Consequently, if a wall require to have a house placed against it, and this house be of the lean-to description, other circumstances being suitable, the wall should run east and west, and the house should be built on the side of it facing south. During that part of the year when the sun rises north of the east, and sets north of the west, such a house would, of course, lose part of both early morning and late afternoon sun. To obviate this objection, if the wall be not too high, a three-quarter span-house can be erected. Any buildings, out-houses, &c., on the north side of such a wall would afford additional protection from cold winds.

If it be necessary to build in the open, a span-house is usually considered the best. In such a case the ridge may run north and south, and the sides face east and west. In this manner each side receives its due share of the sun's rays, the side facing east receiving the whole of the morning and part of the afternoon sun, the side facing west part of the morning and the whole of the afternoon sun. Sometimes it is considered advisable to reverse this aspect for a span-house, by letting the ridge run east and west, and the sides face north and south. In this case the preponderance of sun's rays will, of course, be received on the south side, leaving the north side much cooler. Plants requiring different amounts of solar rays can therefore be grown in the same house.

But it sometimes happens that the choice of aspect is not perfectly open. Perchance it is necessary, in the case of a lean-to, to place the house against a wall which does not face the absolute south point, but is inclined to the east or west. It must be remembered that in such proportion as the east end approaches the south, by so much is the early morning sun lost; and in such proportion as the east end approaches the north, by so much is the afternoon sun lost. If the deflection of the wall from the line of east and west is great, one means of overcoming the difficulty is by building a three-quarter span-house, the rays which would otherwise be lost on the back of the wall would then be caught. The deflection of the wall from the line of east and west may be so great, that the wall may absolutely be north and south. Several courses are then open. The wall may be made sufficiently low for a span-house to be built. Or a three-quarter span-house may be erected. Or if the wall be too high for such a house and a lean-to must be erected against the wall, the greater proportion of the morning sun will be lost if the house be on the west side, and the greater proportion of the afternoon sun will be lost if the house be on the east side of the wall. Or another site altogether may be adopted.

If a combination of houses require to be erected, the broad principles of the foregoing remarks will hold good. In the case of a quadrangular walled garden, with the walls facing respectively east, west, north and south, there is no objection, so far as aspect alone is concerned, for lean-to, or three-quarter span-houses, to be placed on all the four walls. The amount of the sun's rays or the time during which they will have influence upon the houses, will thus be varied in four different ways. The house on the south wall will have the maximum amount for the longest time. The house on the west wall will lose a great proportion of the morning sun, but will catch all the afternoon sun. Such an aspect is frequently considered advantageous, in order, where no (or very little) fire heat is available, that the latest sun heat may be retained by closing the ventilators and thus counteracting, as much as possible, the fall of temperature during the night. The house on the east wall will receive the same amount of solar influence as that on the west wall, but in the morning instead of the afternoon. The house on the north wall will have the smallest amount of solar influence, but in many cases a specially cool house is desirable. In all remarks a west (&c.) house or wall means a house or wall *facing* west (&c.). In deciding upon the question of aspect, much will depend upon the description of plants, &c., grown, the amount of ground at disposal, the dimensions of the horticultural buildings, economy of space, compactness of the structures, accessibility and various other local and incidental conditions.

In selecting the sight, care must be taken in observing whether trees or other objects are likely to obstruct the sun's rays. The question of levels and drainage, &c., must also be very carefully studied. If houses are to be erected, in which, although they may be structures for purely growing purposes, the ladies of the family take an interest and may be expected to visit occasionally, their comfort and convenience should be studied in the selection of a site.

LEVELLING.

THIS is such an important point in relation to erecting horticultural buildings, draining, and laying out gardens, that a few words are absolutely necessary on the apparatus required; the elementary principles of levelling; and their application to houses.

APPARATUS REQUIRED.

A gardener will find it useful to have—Bricklayer's ordinary horizontal and vertical spirit and plumbob levels ; a reel and line ; stakes ; measuring rods ; an ordinary Gunter's chain, which is 66 feet long, having in it 100 links (it will be remembered there are 100,000 square links in a square acre) ; a drainage level (as shown by Fig. 13) ; and two staves:—

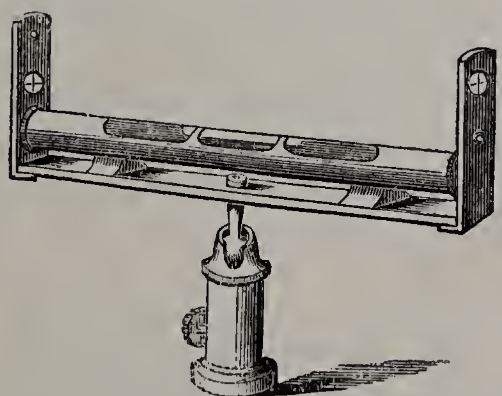


FIG. 13.—Levelling instrument.

See also tools, &c., mentioned in the section "Tool-house."

ELEMENTARY PRINCIPLES OF LEVELLING.

The earth is spherical, and its surface forms a circle, having a radius of 3,956½ miles; consequently an apparent level taken on the earth's surface would form a straight line, whilst the true level should, of course, form part of the above circle. Table VII. shows the height of the apparent above the true level from 100 to 1,000 yards:—

TABLE VII.—DIFFERENCE BETWEEN APPARENT AND TRUE LEVELS.

Yards.	Inches.	Yards.	Inches.
100	0·026	600	0·928
200	0·103	700	1·264
300	0·232	800	1·651
400	0·413	900	2·089
500	0·645	1,000	2·584

Correction of the levels is also required for the refraction of the atmosphere. Although this varies, it may generally be taken at $\frac{1}{7}$ of the correction for curvature. Refraction makes objects appear higher than they really are, therefore the $\frac{1}{7}$ must be deducted from the correction for curvature.

Although it is necessary to mention these points, the errors due to curvature and refraction may be avoided by placing the levelling instrument in the centre of the particular section of ground which is being levelled. Suppose the difference of true level between A and E (Fig. 14) requires to be found, the whole distance must first be split up into convenient levelling sections, of which, in the present instance, we will imagine there are two—A C and C E:—

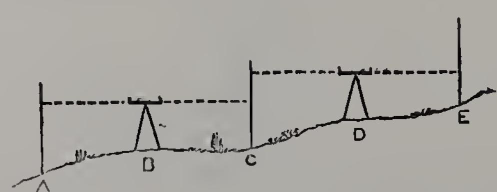


FIG. 14.—Method of long distance levelling.

Staves are fixed at points A and C, the instrument placed midway between them, and the readings of the two staves noted. The operation must then be repeated between C and E. The difference between the sum of the backsights on A and C, and the sum of the foresights on C and E, will show the difference of level between A and E. Thus we will suppose the readings between A and E to be as follows :—

	Feet.	Feet.
Backsight from B on A	10·44	
Foresight from B on C		5·73
Backsight from D on C	9·53	
Foresight from D on E		3·58
	19·97	9·31
	9·31	
Total rise from A to E	10·67	

When the backsights exceed the foresights, the ground rises ; when the foresights exceed the backsights, the ground sinks.

If the total distance to level be great, and intermediate points cannot conveniently be taken, correction for curvature and refraction must be made. This, however, is not likely to occur in connection with horticultural buildings or a garden, unless the exact difference between the levels of a certain spot (say a delivery tank and the distant source of water supply) be required.

When the ground to level is of small extent, the following method may be adopted :—Drive pegs into the ground, in the direction the level requires to be taken, at rather shorter intervals than the length of the ordinary bricklayer's horizontal level. (See Fig. 15):—

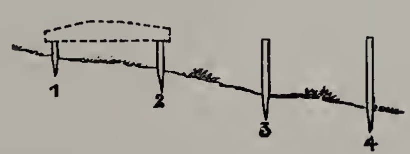


FIG. 15.—Method of short distance levelling.

With peg No. 1 as a fixed point, raise or lower peg No. 2 till the bubble in the spirit tube of the level be central. Then, with No. 2 as a fixed point, raise or lower No. 3 till it be level with No. 2. Then take No. 3 as a fixed point, and repeat the operation with No. 4, and so on. A length of ground up to 100 or 150 feet may be very accurately and quickly levelled in this manner.

LEVELS IN REGARD TO HORTICULTURAL BUILDINGS.

An important object in selecting a site for horticultural buildings, on ground which is undulating or has a general slope, is that there shall, if possible, be rising ground or protection on the north, and a fall, or, at any rate, no obstruction, on the south. Another object is that the buildings shall be capable of easy drainage.

When the ground is fairly level in the direction of the length of the buildings, but rises or falls in other directions, artificial levelling of the ground is seldom required. When, however, the ground is not level in the direction in which the houses are built, several courses are open. First, the house may be made to retain its floor line at the highest level of the ground, as at A in Fig. 16 :—

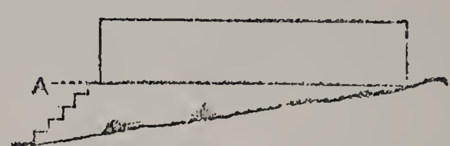


FIG. 16.—Longitudinal block elevation of a house embanked.

Secondly, if the house or houses be very long, and surplus soil can neither be obtained or disposed of, other things being equal, the level may be obtained by half excavating and half embanking, as in Fig. 17 :—

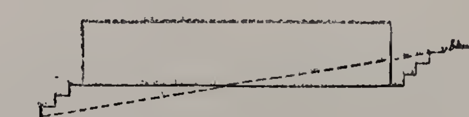


FIG. 17.—Longitudinal block elevation of a house half excavated, half embanked.

Thirdly, if by reason of the excessive fall of ground or length of houses this is not practicable, step-levels may be introduced, as in Fig 18:—

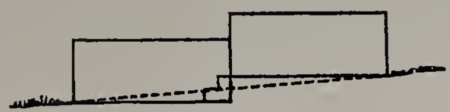


FIG. 18.—Longitudinal block elevation of house on step-levels.

In such a case the boiler would have to be at the lowest end, or at such a depth and in such a position that it can supply, with ease, the lowest house. This third course should be avoided, if possible, as it is not generally advantageous to have the paths in a range at different levels. (See "Paths.") In case, from any reason (such as a difficulty in drainage) the general level of growing-houses has to be raised, it is frequently advisable to reach such level by an inclined plane rather than by steps, so that a barrow may be wheeled direct into the houses. On no account whatever should the line of glass and wood-work be allowed to follow the slope of ground either as in Fig. 19 or 20:—

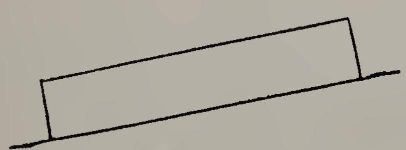


FIG. 19.—Longitudinal block elevation of an unlevelled house (incorrect).

FIG. 20.—Longitudinal block elevation of an unlevelled house (faulty).

The author has seen such houses, but for ordinary horticultural work they are unnatural, inconvenient and hideous. Sometimes long corridors are constructed as shown by Fig. 20, but they would be much more sightly, if, while the floor-line followed the slope of the ground, the roof were to be constructed of step-levels, as shown by Fig. 18. A good instance of this is the long corridor leading from the Crystal Palace to the London and Brighton Railway Station.

All the above remarks will apply to combinations as well as single houses. In the case of combinations, however, the houses composing each set should, if possible, be on the same level. Parallel lines of houses may occupy different levels. In fact, while not sacrificing cost, sightliness, utility, &c., to uniformity in levels, aim at the latter whenever possible. The floor-lines of conservatories and horto-architectural structures, when not dependent upon the level of other reception-rooms, should be two or three steps above ground-line, as much to produce effect as to facilitate drainage. The floor-level of a conservatory which communicates with a dwelling-house should be about the thickness of a mat, but no more, below the level of the communicating reception-rooms. (See "Paths" and "Show-houses.")

DRAINAGE.

GENERAL REMARKS.

IT would be possible to give a large mass of information on the subject of draining land. Such information would embrace geological data, with deductions, and a branch of mechanics, which, however useful to the gardener, would be irrelevant to the present work. It is therefore proposed to give merely one or two useful tables, a few general remarks, and then some practical notes on drainage in relation to horticultural buildings proper.

In planning drains, Hurst recommends that the figures given in Table VIII. be taken to represent the quantity of water per hour for which draining provision should be made.

TABLE VIII.—PROVISION FOR DRAINING VARIOUS SURFACES PER HOUR.

Draining Surface.	Ins. of Water in Depth.	Gallons per 1,000 square feet.
From Roofs (horizontal measure) ...	·5	260
,, Paved Surfaces	·1	52
,, Gravel (Clay Subsoil)	·05	26
,, ,, (Gravel Subsoil)	·01	5
,, Meadows or Lawns	·02	10

In open country, where the soil is loose and permeable, about one-third only of the rainfall finds its way into the watercourses, the remaining two-thirds being absorbed or evaporated. Table IX. will give other data in regard to the drainage of land.

TABLE IX.—DRAINAGE OF LAND (MOLESWORTH).

Soil.	Depths of Pipes.		Distance of Pipes apart.
	ft.	in.	feet.
Stiff Clay	2	6	15
Friable Clay...	2	0	18
Soft Clay	2	9	21
Loam, with Clay...	3	2	21
,, Gravel	3	3	27
Light Loam	3	6	33
Sandy	3	9	40
Light Sand, with Gravel ...	4	0	50
Coarse gravelly Sand	4	6	60

The nature of the surface of the soil must be taken in conjunction with the subsoil and direction of the strata. A garden may slope towards the south, and yet a retentive undrained subsoil may neutralize surface advantages. Any chilling effect which spring water in the soil may produce must be guarded against. Open drains and covered rubble drains are used in land drainage, but pipe drains are chiefly adopted. The angle on plan, which a subsidiary drain makes with a main drain, is frequently 90°, but before making the juncture, the former should gently curve so that, on joining, its contents may flow in the same direction as the contents of the latter. The former should, moreover, whenever possible, have a decided fall into the latter.

In draining a garden, especially of clay or heavy soil, it is frequently advantageous to sink a central well, with a dome-top rising just above the ground, and having a man-hole in the centre covered by a substantial trap-door. Drains from the various parts of the garden may be discharged into this well, which should be provided with an overflow pipe at a lower level than the inlet discharge pipes. By opening the trap-door, it can easily be seen if all the drains are working properly. The discovery of a stoppage in any one of the drains is thus facilitated.

DRAINAGE OF HORTICULTURAL BUILDINGS.

If the ground descend in any direction towards the buildings, care should be taken, especially if the subsoil be non-absorbent, that due provision is made for surface as well as underground drainage, and that the water does not find an artificial reservoir in the stoke-hole, main pipe trenches, borders, &c. If there be no other means of keeping the water out of any low lying part, such as a stoke-hole, either sink a galvanized iron tank in the ground and build the stoke-hole in it (in this manner keeping the water out instead of in) or else sink a well and drain into it. It is perfectly useless to think of keeping refractory water out of a stoke-hole by building the latter of concrete, hard faced bricks, hydraulic cement, or any combination of the three.

Of course there is one other course open when a stoke-hole cannot easily be drained, namely, to raise the datum floor-line of the houses above the level of the surrounding ground, when the stoke-hole need not be sunk so low as would otherwise be necessary.

When deciding the question of drainage, it is advisable to make a note of the most suitable positions for the down rain water pipes from the roofs. Down pipes should never be connected with the drains, but should discharge into gratings. In this manner the down pipes can easily be kept clear of obstructions. When constructing drains for horticultural buildings it is often necessary to unite to them the drains for carrying away surplus water from stables, outhouses, &c.

The question of the drainage of horticultural buildings has such an intimate connection with water supply, that the foregoing remarks should be read in conjunction with the sections upon the collection, retention, and distribution of rain water.

GROWING-HOUSES.

LEAN-TO HOUSES.

THE *raison d'être* of this form, as indeed of the other forms of glass-houses, has already been shown. (See "Aspect and Site," p. 26.) Lean-tos are generally used :—When a wall or building already exists, against which it is desired to place a glass-house—When a wall is specially built, in order that a house or combination of houses may face the south and have brick protection from the north—When the exigencies of the plants, &c., to be grown, demand this form. Lean-to houses facing south are easier to heat than span-houses, and are, other things being equal, cheaper to build than any other form. It must not be forgotten that even when facing exactly south, lean-to houses lose, in the hottest weather, the early morning and late evening sun. Also that a plant, if unmoved, does not catch the sun's rays all round it in a lean-to.

The most usual form of lean-to is shown by Fig. 21, p. 39. This house has about 2′ 6″ front wall and 2′ 6″ vertical light, making about 5′ 0″ in front. These, varied a few inches either way, make very good front dimensions of lean-to for most growing purposes. For plants, 2′ 6″ forms a very good height for front stage; or a raised border or internal bed suffices to lessen the height for stems of vines, &c., which are required to be trained along the glass. In this form, top ventilation is shown by lights hinged to ridge, and bottom ventilation by front lights swinging from the gutter plate. Of course, when considered advisable, these lights may be fixed and ventilators built in the brick-work, as shown by dotted lines. Or both may be used, especially when, as in severe weather, it is sometimes required to heat the incoming air before reaching the plants, by admitting it near the pipes placed immediately behind the front wall.

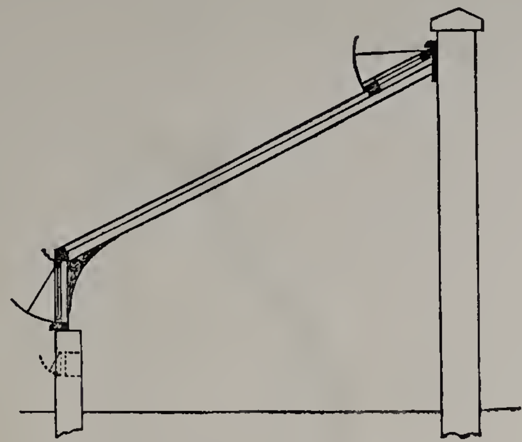


FIG. 21.—Section of lean-to house with front lights.
Scale, $\frac{1}{8}$ inch = 1 foot.

Another lean-to, see Fig. 22, has the same form as shown in Fig. 21, but

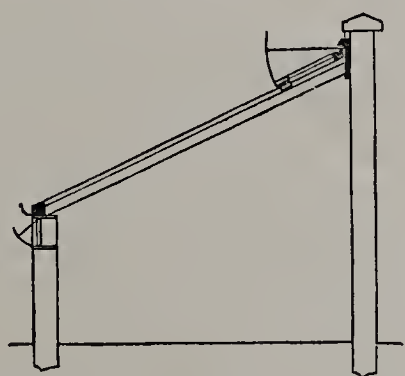


FIG. 22.—Section of lean-to house without front lights.
Scale, $\frac{1}{8}$ inch = 1 foot.

without vertical glass lights. Bottom ventilation is provided by swinging shutters in brick-work, top ventilation by sashes hinged to ridge. About 4′ 0″ forms a very good height for front wall. This is high enough to admit a front stage for bedding stuff, &c., and low enough, with a raised border or inside bed, to accommodate vines, &c., to be trained near the glass.

With equal areas, Fig. 22 can be built somewhat cheaper than Fig. 21. By decreasing the height of the front, Fig. 22 is found advantageous for those trees, &c., which require a minimum space between the soil they grow in and the spring of roof. Of course, this is presuming that head room is not required inside near the front.

Another form of lean-to is shown by Fig. 23.

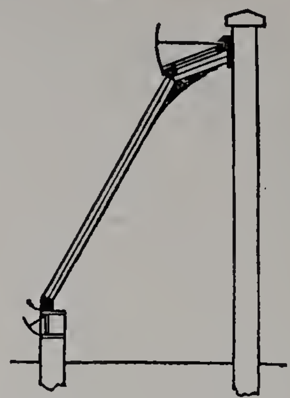


FIG. 23.—Section of narrow lean-to house, broken roof.
Scale, $\frac{1}{8}$ inch = 1 foot.

This has a broken roof, or roof of more than one pitch, a very low front wall supplied with ventilators, and top ventilators similar to the two preceding figures. The first, or steepest slope, is sometimes made of framed lights, which are capable of being taken off when a very large amount of air requires to be admitted to the house. This form is frequently used where wall-fruit requires protection, and the house must be narrow, so that there may be the minimum distance between the glass and the trees on the back wall, thus counterbalancing any disadvantage which may arise by the main portion of the roof being of a higher pitch than is theoretically advisable. Such a house may sometimes be advantageously fitted with vertical front lights 2 feet high, coming down to within 6 inches of the ground, in order that strawberries, &c., may be grown immediately in front of the lights. To cause as little obstruction as possible, where there is an outside as well as an inside border, part of the front wall may give place to iron pillars and slate slabs. (See "Brick-work.")

Another form of lean-to house, but one which is not often seen, is similar to Fig. 22, but instead of having any vertical front, the roof springs practically from the ground line. The advantage of it is, of course, that the sun's rays come directly on the ground, and no length of stem whatever need intervene between the border or bed and spring of roof. This very fact, however, may be a disadvantage, as it is not always possible that the soil of the front part of the border or bed can be protected by the shading of foliage, and it may sometimes be advisable to have a small dwarf wall in front to assist in shading the soil. In addition to this, although such a form of lean-to admits of top ventilation in the ordinary way, it does not easily admit of bottom ventilation. The only way such a house can be at all adequately ventilated, is by having sashes opening in a line parallel with the rafters. This mode of ventilating from the bottom to the top of a roof is not always considered advisable, especially if the house be heated, and the temperature of the incoming air requires to be raised before touching the foliage.

In all these figures an imaginary ground line is shown at the same level inside the houses as out. But of course it may be necessary that this datum line should vary, as, for instance, if the houses have to be partially sunk to afford minimum obstruction, or have to be raised by reason of defective drainage or inability to sink stoke-hole so low as is necessary. Or, for architectural purposes, the exterior level may require to be much lower than the interior floor line, as it may often happen that an important appearance must be given to the exterior, without increasing the height inside between ground and spring of roof. In this case, the interior datum line may be level with the top of dwarf wall, and the exterior ground line 2′ 6″ or 3 feet lower, so that a house may have 8 feet front vertical height outside, and only 5 feet front vertical height inside.

It must not be forgotten, too, that, other things being equal, it is more costly to sink a house in the ground, than to have the floor at, approximately, the same level as the exterior ground.

SPAN-ROOFED HOUSES.

Next to lean-tos, span-roofed houses possess the most natural and advantageous form. They are very useful:—Where no wall exists or is required—For building at right angles to and in combination with a range of lean-to houses against a south wall—When the minimum height is required, so that there may be as little obstruction caused as possible—When plants require to be as near the glass as practicable—Or when the length of the houses must be in the direction of north and south, and each side requires an equal amount of the solar rays.

Usually, span-houses are placed with the ridge running north and south, so that there may be as perfect a distribution of the sun's rays as possible on every side of a plant. Or, if it be advisable that one side of the house shall be hotter, and receive a greater proportion of the sun's rays than the other, then span-houses are frequently placed with the ridge running east and west, and such houses for a great many purposes are extremely useful.

A general form of span-house is given in Fig. 24:—

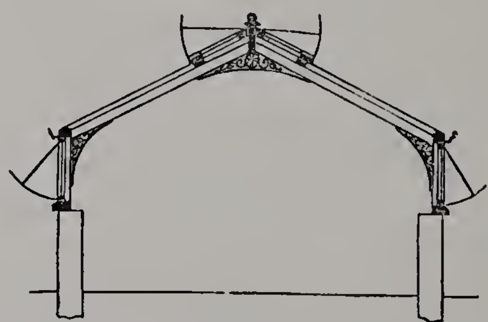


FIG. 24.—Section of span-house, with front lights.
Scale, $\frac{1}{8}$ inch = 1 foot.

This is shown with 2′ 6″ brick-work, and 2′ 6″ vertical light. All these vertical side lights can open as bottom ventilation, with the substitution or addition of ventilators in brick-work, especially for use in severe weather, or when the external air requires to pass over pipes before coming near the plants. The top lights alternately on each side of ridge, or all the lights along one side of ridge, or all the lights on both sides of ridge, may be made to swing open, as local circumstances, the produce to be grown, &c., may demand.

Taking away the side lights, we have Fig. 25 :—

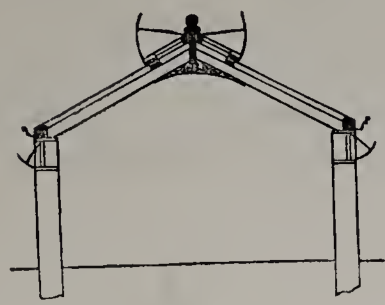


FIG. 25.—Section of span-house, without front lights.
Scale, $\frac{1}{8}$ inch = 1 foot.

This is practically the span counterpart of the lean-to house, Fig. 22. The top remains the same as in the previous illustration, but the lower ventilation is provided by flap, hit-and-miss, or other approved ventilators in the brick walls. 4′ 0″ height to eaves is shown, but this may be varied to suit the different purposes for which the house may be required. This dimension, however, is found suitable when either staging, a raised border, or an artificial bed is required. With a uniform width and length of house, Fig. 25 would not cost so much to build as Fig. 24.

Another form of span-house is given in Fig. 26 :—

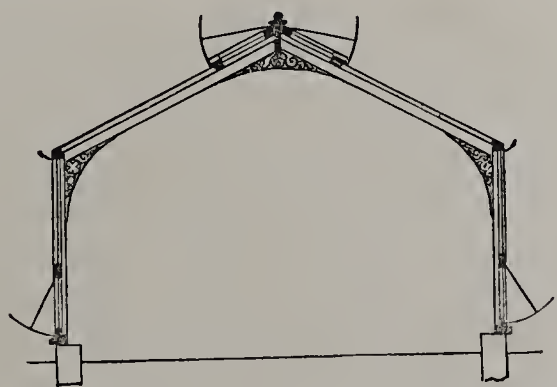


FIG. 26.—Section of span-house with high glass sides.
Scale, $\frac{1}{8}$ inch = 1 foot.

This shows 6′ 0″ of vertical glass-work coming practically down to the ground line, ventilated at top and bottom, in the same manner as

Fig. 24. This is a useful form of house:—When a fairly large cubical contents is required, in order that the temperature of the interior may not fall so rapidly—When an unheated structure is necessary, and the sun's rays must be admitted with as little obstruction of walls as possible—When large plants require to be planted in open borders.

Fig. 27 shows a span-house of a larger and more pretentious character.

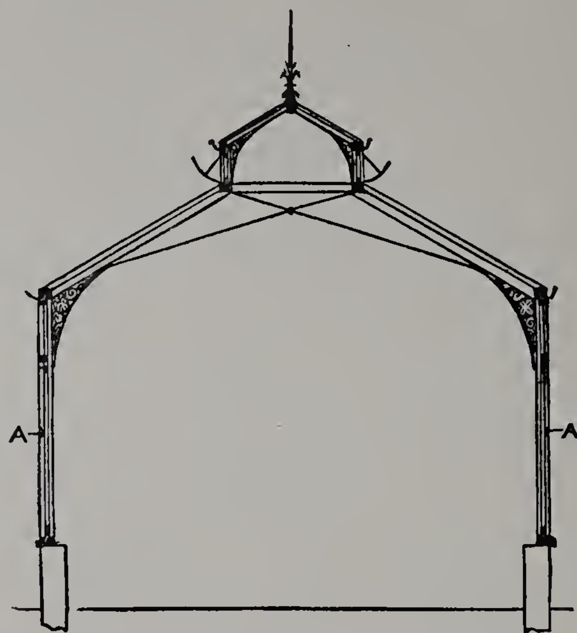


FIG. 27.—Section of large span-house.
Scale, $\frac{1}{8}$ inch = 1 foot. *A A*, casement lights.

The lantern breaks up the roof, and while, by the additional framework, extra obstruction is presented to the sun's rays, yet for a large and important style of work such a form frequently becomes necessary. Such a house, although sometimes used as an orchard-house, cannot strictly be called a growing-house. It is, by the height to eaves, and general proportions, more suitable as a show-house, floral corridor, horticultural promenade, conservatory, &c.

Another form of span-house is that in which the roof has more than one pitch. This does not possess the same advantages which are attached to certain lean-to houses having a double pitch. If used as a plant-house fitted with interior stages of a normal height, and the glass is practically carried down to the ground, all the glass below the stage-line is not only useless, but the external appearance is not so pleasing, in consequence of the stage-line cutting the view of the glass. Efficient ventilation of this form of house is not so easy. The first pitch of roof is almost certain to be too steep in accordance with the principles laid down in the article "Inclination of Roofs," p. 18, *et seq.* Plants near the lower part of the roof fare pretty well, but near the centre of the house would be much too far from the glass. For ordinary hot-house purposes such a form has no great advantages. For vinery purposes this house would be much more suitable, were bottom ventilation capable of being more easily carried out, say by having 2 feet dwarf walls fitted with opening ventilators.

Another form is that in which the roof practically springs from the ground line, and really may be said to be the same as shown in Fig. 25, leaving out the dwarf walls and lower ventilators. The sun's rays can certainly reach every part of the internal area, but are apt to bake the ground near the sides. Top ventilation is, of course, easy, as in any other of the span roofs, but bottom ventilation is difficult; or, in fact, any ventilation by which air requires to pass near hot water pipes before touching the foliage. This may be a cheap form of house, but cannot be termed efficient.

Curvilinear span-houses are treated in an article specially devoted to this form of structure.

In a lean-to the solar rays are directed to a plant principally on one side, and there is part of a plant which, if kept in a lean-to unmoved, receives no direct rays at all. In a span, however, the rays reach both sides of a plant, and more uniform growth is promoted.

Other things being equal, heat is not so easily retained in a span as in a lean-to. This is especially the case if the ridge be in the direction of east and west, as radiation is more easily carried on by a glass roof and lights facing north than by a brick wall, especially if the latter be protected by potting-sheds, furnace-room, mushroom-house, &c., &c. Therefore, a span-house requires more heating power to produce the same effect than a lean-to of corresponding area.

The area of roof in a span-house is equal to that in a lean-to of the same pitch and width, but, of course, the difference in vertical height between the lowest and highest points of roof is twice as much in the latter as in the former. Thus it will be seen that span-houses are more advantageous for plants which require to be near the glass, and the necessity is obviated of having such a lofty stage as would be required in a lean-to. Span-houses of an ordinary width are applicable where no great length of continuous rafter is required.

In all cases the same remarks as in the section on "lean-to houses" apply to spans as regards interior and exterior datum lines being adapted to suit drainage, stoke-hole depth, appearance, architectural requirements, obstruction of view or light, and cost.

THREE-QUARTER SPAN-HOUSES.

These are very frequently termed half-span, but it will be seen that "half-span" really indicates a lean-to, thus :—

Therefore a three-quarter span is the better term for a roof of unequal span, in which one side of the span is longer than the other. The annexed figure shows one of the usual three-quarter span-houses :—

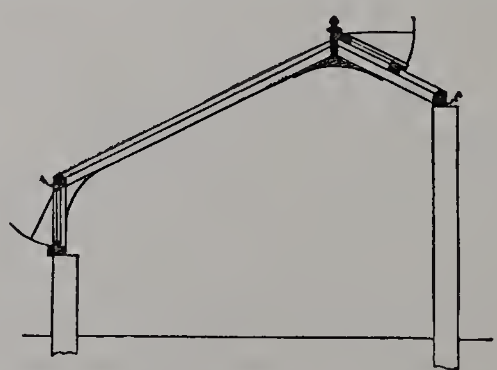


FIG. 29.—Section of three-quarter span-house.
Scale, $\frac{1}{8}$ inch = 1 foot.

They are useful:—Where a back wall requires to be moderately low—Where a maximum length of rafter is not necessary—Where, by themselves or in combination with other houses, it is advisable to let light in at the back—Where a certain inclination of roof is required without altering the width or raising, any more than is absolutely necessary, an existing back wall—Where heat requires to be saved by truncating the apex of an otherwise lean-to—Where the height of the back wall of a lean-to is objectionable, but yet brick protection is desired on one side, in combination with a means of easily providing for potting-shed, tool-house, mushroom-house, &c.

Three-quarter span-houses are applicable to much the same conditions as lean-tos, and the remarks in the preceding section will generally apply to this. Their best aspect is to face the south, when they catch, not only the same amount of sun's rays as lean-to houses, but what the latter fail to catch, viz., all the rays when the sun rises north of the east and sets north of the west, or the early morning and late afternoon sun during the long days. Like lean-tos, three-quarter span-houses, when facing south, are easier to heat than span-houses of corresponding dimensions, owing to the protection of the north wall. Supposing the pitch on each side of the ridge is the same, the area of roof is exactly equal to that of a lean-to or span of the same length, width and pitch.

The three-quarter span form is very convenient in some cases when it is desirable to have the top ventilation hidden from sight, or when, for architectural effect, an ornamental ridge is advisable, yet the house requires to approximate as nearly as possible to the lean-to form. Unless in combination with other houses, or to fulfil some special object, three-quarter span-houses may be generally considered unsightly.

CURVILINEAR HOUSES.

These have been extolled at various times as possessing the most advantageous form for growing purposes, but upon a consideration of their claims, it is open to question whether their advantages are not overwhelmed by their disadvantages.

Other things being equal, a curvilinear roof doubtless admits the solar rays in a better manner than any other form of roof. But it must be remembered that the sun's rays are, so far as the earth is concerned, practically parallel; so that at no time can they impinge upon the whole of a curvilinear roof at right angles, as they can upon a straight roof, thus :—

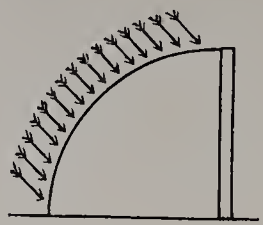


FIG. 30.—Vertical block section showing sun's rays striking a curvilinear roof.

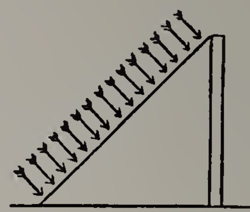


FIG. 31.—Vertical block section showing sun's rays striking a flat roof.

Scale, $\frac{1}{16}$ inch = 1 foot.

Suppose the rays impinge on the centre of the roof, Fig. 30, at 90°, it will be seen that the angle steadily decreases as the rays approach the bottom or top of the roof. This, however, is not of so much importance when we consider that the angle of incidence may vary 20° or 30° without decreasing the amount of sun's rays transmitted. Then again, suppose the centre of the curve is taken at the bottom of the back wall, as in Fig. 30, the top of roof will approach the horizontal, and the bottom of roof will approach the vertical, thus increasing the liability of rain to drift in at the top, between the laps, and also form a lodgment for the snow. This may, of course, be remedied by making the centre of the curve below and behind the bottom of the back wall, thus :—

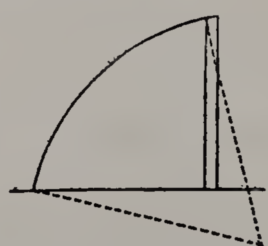
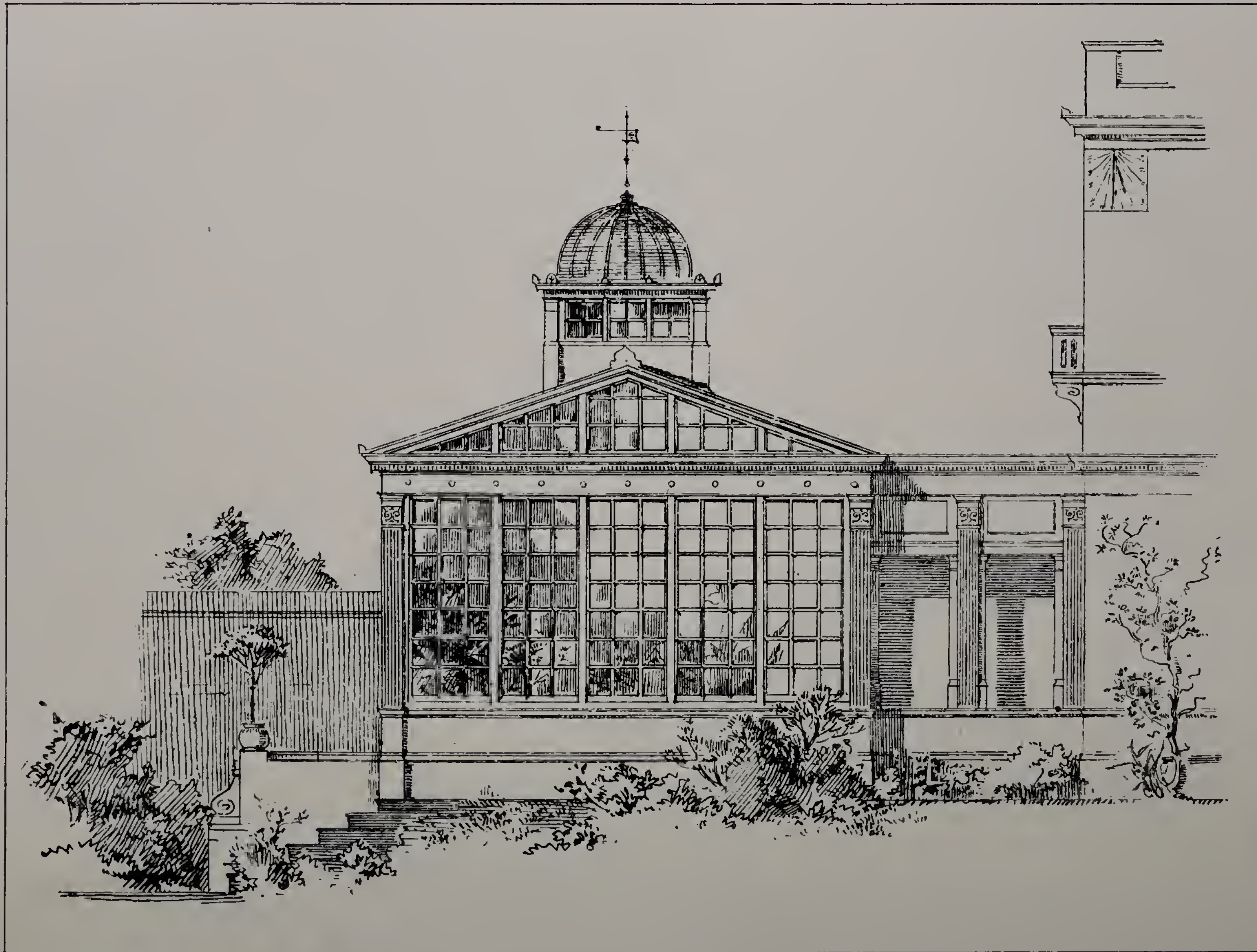


FIG. 32.—Vertical block section showing a mode of determining the radius of curvilinear roof.
Scale, $\frac{1}{16}$ inch = 1 foot.

This mode cuts off the extreme vertical and horizontal portions. But even



supposing this done, it is difficult to construct ventilators which shall form part of the curve. The construction of the framework of a curvilinear roof, either in wood or iron (in small work), is more costly and troublesome than that of a straight roof, and lateral thrust is not so easily overcome. Training wires are not so easily fixed, and heavier iron vertical rods are required if it be necessary to follow the exact curve of roof. If bent glass be used, it is not only much more costly at first, but much more expensive to keep in repair, and much more susceptible, by changes of temperature, to breakage than flat glass. If, to obviate these disadvantages, the roof is made up of straight panes of glass, these must be short, or they will not follow the bend of roof. In either case they look bad, unless the curve has a very large radius indeed. The glazing of straight pieces of glass on a bent rib is also not easy.

Taken as a whole, circular work may in a few exceptional instances be introduced to obtain an architectural result, or in moulding the lines of a large winter garden or magnificent palm-house, but for ordinary growing purposes, we may consider curvilinear roofs not so suitable as those composed of straight lines.

RIDGE AND FURROW HOUSES.

By a "ridge and furrow" house is usually meant a house having a roof composed of a number of small spans. If a house, say 45 feet wide, be required, the lean-to form, even with the lowest practicable pitch, would cause the roof to be inordinately high. A single span-house, with the same pitch, would reduce the height of roof one-half, but even then it would, probably, be much higher than is convenient for either growing or architectural purposes. It might be, under these circumstances, doubtless advantageous to split up the roof into say 3 spans of 15 feet each, or a central span of 20 feet and two subsidiary side spans of 12½ feet each. But neither of these roofs could with justice be called a "ridge and furrow" roof. If, however, the roof were split up into 9 spans of 5 feet each, this would then be a ridge and furrow roof proper. The above roofs are shown in Fig. 33—viz., lean-to, single span, 3 span and 9 span "ridge and furrow"

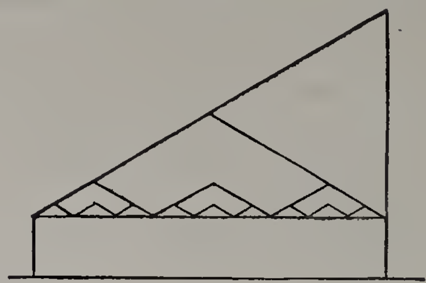


FIG. 33.—Vertical block section showing modes of constructing a roof of various spans. Scale, $\frac{1}{32}$ inch = 1 foot.

roofs. Of course we are now treating the roof simply in relation to ridge and furrow principles; doubtless a house 45 feet wide could be treated better by having a roof of a design perfectly different from any of those shown.

Now it is obvious that (exclusive of the gables):—All the above roofs have the same amount of glass area—That the smaller the number of spans, the greater the area of glass in the gables—That, so far as shape alone is concerned, the amount of solar rays admitted by the roof would vary only in an insignificant degree if it were composed of one, three, or nine spans, provided the pitch and aspect remained the same—Also that, the greater the number of spans, with the greater ease can a uniform distance be maintained between the plants and the glass. But the greater the number of spans, the greater the number of valley gutters and ridges. Consequently the larger is the area of obscurity formed by them, and the greater are the constructional difficulties connected with keeping these valley gutters water-tight and in good repair, and in properly supporting the roof. Therefore we may safely conclude that, given the necessity to treat a roof on the span principle, a ridge and furrow roof proper admits less light and is more difficult of construction and maintenance than a roof having the smallest practicable number of spans.

When Sir Joseph Paxton designed the large conservatory at Chatsworth and also the 1851 Exhibition, now the Crystal Palace, it was considered that he had solved a great problem in connection with horticultural buildings, but subsequent experience has proved that the ridge and furrow mode of construction, however it may be adapted for railway stations and large buildings, presents, at any rate for ordinary horticultural work, more disadvantages than advantages, especially when cost of maintainance is of consideration.

IRON *v.* WOOD HOUSES.

There can be no doubt that a building constructed of iron requires a smaller bulk of material to possess a given strength, than one constructed of wood. Therefore the framework of an iron house cannot obstruct so many solar rays as a corresponding one of wood. This is especially the case when the sun is shining on the roof obliquely, for the shallow iron bars and rafters will throw a much smaller shadow than the thicker and deeper wood bars and rafters. Then, again, iron houses will last longer than wood, provided the material is kept well protected, by paint, from the action of the atmosphere. If not kept well painted, and allowed to rust, they will not only wear out rapidly, but the rust drip produced by the condensation of moisture will be very disastrous to plants.

On the other hand, iron houses are more costly than corresponding houses of wood, as iron is not worked with so much facility as wood; ventilators of iron houses are frequently found unsatisfactory, and not sufficiently tight to enable the house to be well fumigated, especially in cheap iron houses. Ordinary sized conservatories (not of course winter gardens or other large structures) are not capable of such effective architectural treatment in iron as in wood, as those made of the former material are apt, unless constructed inordinately massive, to look "wiry." Glass is frequently found to break much in iron houses, owing, so some people say, to the expansion of the iron. But it will be found that this defect is generally owing to the expansion of the *glass* against the non-resisting metal, rather than to the expansion of the metal itself; especially if the glass has been cut, in the first instance, to fit accurately between the sash bars. The linear expansion by heat from 32° to 212° Fahr., is

Of Glass,	1	part	in	1161.
,, Cast Iron,	1	,,	,,	889.
,, Wrought ,,	1	,,	,,	819.

So that if a pane of glass be 10″ wide and a wrought iron sash-bar

$\frac{1}{8}''$ thick, the pane of glass will expand ·000861 inch and the sash bar only ·000015 inch, on the temperature being raised from 32° to 212°; or in the ratio of 861 to 15. Of course there is the expansion and contraction of tie rods or constructional parts by which the house is held longitudinally. So that there may be various strains causing the panes to deviate from their rectangular shape, when of course breakage will occur. But provided iron houses are constructed in a proper manner, fitted and erected by experienced men, and the glass put in with a certain amount of "play," no difficulty will be found to exist by glass breaking. With thoroughly good work in iron houses, ventilators and other adjuncts will be certain to fit well; but with cheap inferior work iron houses will prove a continual source of annoyance. Where curvilinear work is considered necessary or desirable, iron bars and ribs may be judiciously used instead of wood. Iron is a good conductor of heat (the ratios being:—iron 450, glass 14, deal 3) consequently an iron framed hot-house would radiate internal heat much more rapidly than a wood framed house. Chiefly for this reason, growing-houses or houses required to be kept at a high temperature are seldom constructed of iron.

We have hitherto been speaking of houses in which the framework is wholly constructed of iron. A compromise is, however, not only possible, but frequently judicious, and some of the best growing-houses to be seen, are those which have been constructed of a combination of wood and iron. These have some of the parts most difficult and costly to work, when made entirely of iron (such as plates, sills, mullions, posts, &c.) constructed of wood. The rafters are also of wood, much lighter than usual, but made amply strong by light iron tie rods. The intermediate vertical and roof sash bars, the purlins, also some of the hanging lights, are made of light but effective sections of **L** and **T** iron. In this way very strong, durable, and light houses can be constructed, admitting the maximum amount of solar rays, and casting very little shadow, no matter at what obliquity the sun happens to be shining.

Independently of any other considerations, where first cost is of importance, wood houses, or a combination of wood and iron, is to be recommended in preference to those entirely of iron, as it is not advisable to build the latter unless they are carefully and accurately fitted; and careful, accurate fitting, no matter what labour-saving contrivances may be employed, mean extra expense. Wood houses, if properly constructed and kept well painted, are very serviceable, and will last a long time.

WALL-TREE PROTECTORS.

A wall affords a certain protection, contingent more or less upon its aspect, to trees growing against it; but this protection is not always sufficient. A coping of some material placed on the top of the wall, has been found not only effectual in protecting the trees from some of the disastrous consequences of autumnal rains, but also to a great extent from late spring and autumn frosts. Even a simple coping, however, may not be advisable at all seasons, especially when the trees do not require to be kept from summer dews. On the other hand, when the fruit and wood are ripening, protection from wasps, birds, &c., as well as from cold and wet, is found very advantageous. In other words, the conditions to fulfil are:—cheapness; extreme portability; power of partial or entire ventilation; no skilled labour or excessive time occupied in erection, manipulation, or taking down. To fulfil all these conditions various schemes have been adopted. Permanent copings of stone or cement have given way to temporary copings of wood, &c. Tiffany, netting, and other materials have been employed to hang from the coping in front of the wall. Horticultural builders have brought out portable glass copings, supported by brackets bolted to or through the wall (see Fig. 34), or by posts from the ground

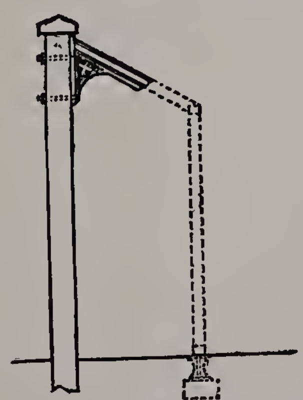


Fig. 34.—Vertical section of wall-tree coping and cover. Scale, $\frac{1}{8}$ inch = 1 foot.

in front. The glass on the coping, or the whole coping itself, being easily removable when desired. Then there has been vertical glass and net protection, formed by upright portable glazed frames or wire netting, supported between the bottom plate of the coping and a sill resting on iron shoes or short posts fixed in the ground.

Mr. Rivers invented an ingenious form of wall-tree cover of which the design has been registered. (See Figs. 35 and 36.)

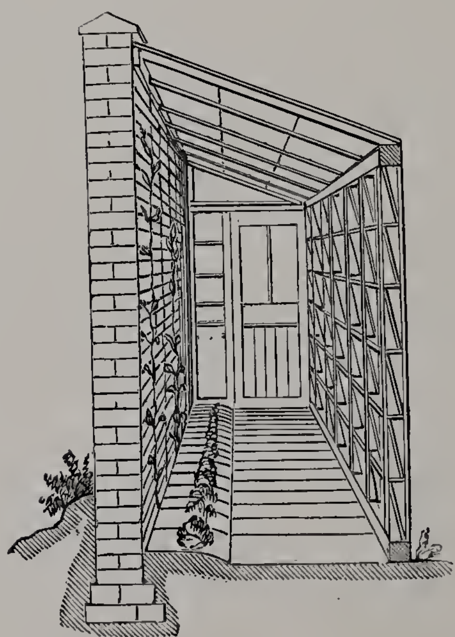


FIG. 35.—Interior perspective of Rivers' wall-tree cover. (Registered by Dennis & Co.)

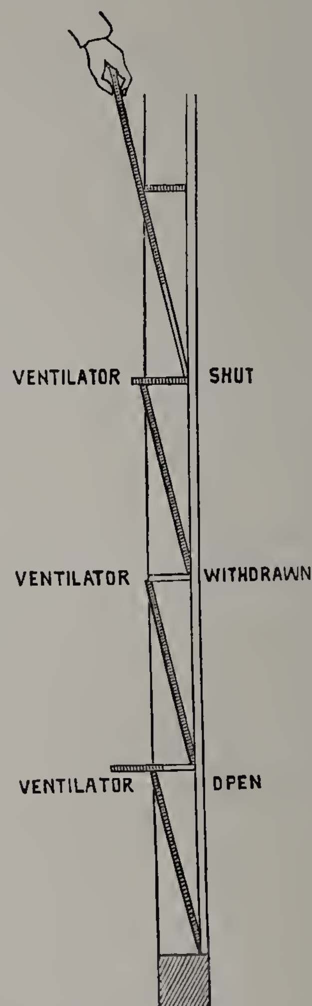


FIG. 36.—Vertical section of front of Rivers' wall-tree cover.

Upright pieces of wood are placed at distances of about 24 inches apart. Horizontal and diagonal grooves having been cut, glass is slid in them between the uprights, and forms the necessary protection. If a small amount of ventilation be required, the horizontal strips of glass are taken out. Pieces of perforated zinc slipped in their place will prevent wasps, &c., entering. If the whole or part of the front requires to be open, as much of the glass as is necessary can easily and quickly be taken out, and as easily and quickly slipped back when required. This is about the simplest and cheapest form of wall-tree cover manufactured.

Permanent wall copings are usually made to project not more than about 6″ over the wall. Temporary wood copings are made to project 9″, 12″, or even more. Glass copings are made 1′ 6″ to 4′ 0″ wide, and these copings with combined vertical protection up to 6′ 0″ wide. In any case permanent copings cannot be recommended.

Protectors for wall fruit, as described above, can be constructed in various ways, and may prove very useful. But it will generally be found that at best they are a makeshift, and that with a trifling addition to the first cost, an efficient and serviceable permanent lean-to house can be erected, by which, even without, but especially with, a heating apparatus, results of a more satisfactory and reliable character can be obtained. In this case reference should be made to the section "Lean-to Houses," p. 38 *et seq.*

COMBINATIONS OF BUILDINGS.

The futility of attempting to treat this part of the subject in detail, is conclusively shown when we consider that, according to the laws of permutations, with, say twelve conditions, no fewer than 479,001,600 different changes can be obtained. There are a great many more than twelve conditions which go to make up the most advantageous combination of horticultural buildings, therefore we can only indicate here what some of those conditions are, give a few hints regarding them, and annex one or two illustrations of combinations which may be serviceable under certain circumstances.

The arrangement of any combination of buildings will depend upon, amongst other things:—The size of the establishment—The amount of money to be devoted to the purpose—What is required to be grown—If fruit or flowers must predominate—Whether space has to be devoted chiefly to specimen plants or general purpose produce—Whether the luxuries or the necessaries of fruit are required—Whether the produce is chiefly required for show or utility—Whether in or out of season—Whether much or little forcing is necessary—The tastes and habits of the proprietor—The exigencies of the site and constructional requirements. Not only will these and other conditions determine the class of buildings to be erected, but more especially the proportions which the various parts of a combination must bear to one another.

A wall may already exist, against which it is expedient to erect a range of buildings. No wall may exist, but it may be considered advantageous to erect one, in order, not only that a lean-to range may be built against it, but to provide an available north wall for boiler-house, potting-shed, &c., &c. Or, again, no wall may exist, and it may be necessary for the combination of buildings to take the low span type, in order that a high wall or similar obstruction may not be required.

In any case horticultural buildings should be planned so that they are compact, not straggling; so that the buildings for consecutive operations may be arranged, as nearly as possible, in consecutive order; so that there may be no long undivided houses; so that the boiler is in a convenient position for the work which it has to do; and so that each separate building does not suffer in efficiency through being placed in combination with others. If a certain combination is desired, but the expense of building such a combination at one time is too great, it is better to build part at first, and leave the remainder till later, rather than lessen the first outlay by decreasing the efficiency of the whole combination. A plan favoured by some, is to build span-houses together, so that each of the inner walls is common to two houses. See Fig. 37:—

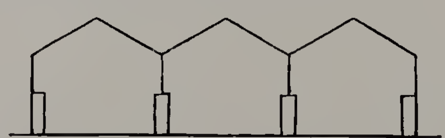


FIG. 37.—Vertical block section of combination of span-houses. (Faulty.)

In this manner, if three houses are built, of course two vertical walls are saved; but it must be remembered that the inner house can have no bottom ventilation along the sides, and that each of the two outer houses can have bottom ventilation only along one side. Where a combination of lean-to or three-quarter span-houses is built against a south wall, it is frequently advantageous to have span-houses meeting the combination at right angles, but these span-houses should not be so long nor so high as to cause solar obstruction to the other houses.

Fig. 38 shows a combination which may be suitable for a moderate-sized garden :—

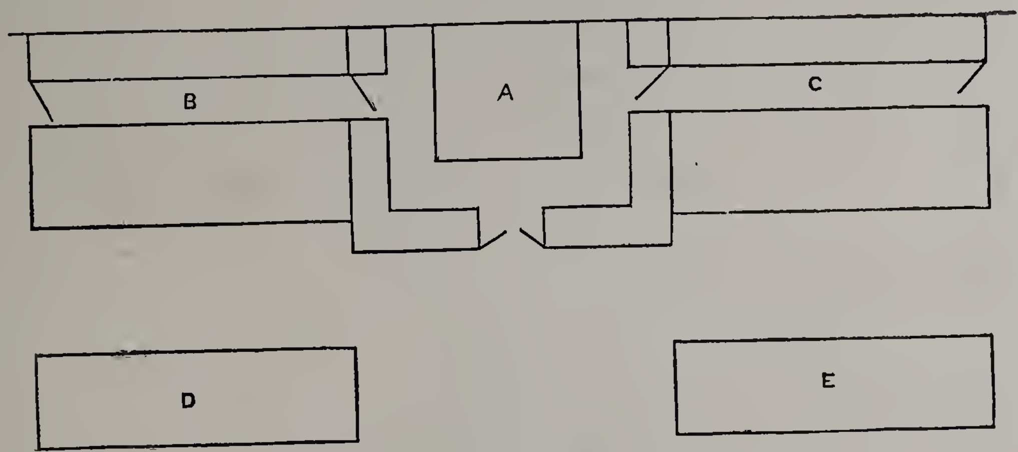


FIG. 38.—Block plan of moderate-sized combination of houses.
Scale, $\frac{1}{16}$ inch = 1 foot.

A	Three-quarter span	... ...	Plant House.
B	Lean-to	... ...	Stove or Vinery.
C	Lean-to	... ...	Vinery.
D	Pits	... ...	Cucumbers or Melons.
E	Pits	... ...	Bedding Stuff, &c.

This consists of a central three-quarter span and two lean-to houses. The wall-plate at back will be at the same level throughout, if the projection of centre house in front, and perhaps its higher eaves, are allowed to compensate for the decreased proportional height at back of it. In addition to this range, there would be isolated rows of frames in front, part heated for cucumbers, &c., the remainder unheated for bedding stuff and other general purposes.

Fig. 39 shows a ground plan of a combination suitable for a larger establishment :—

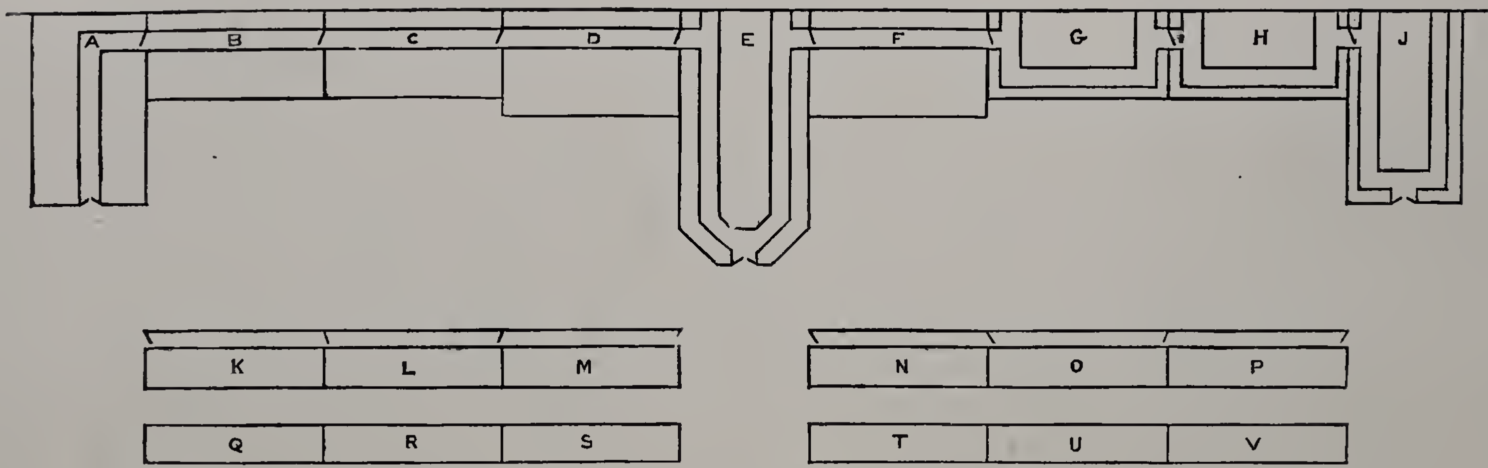


FIG. 39.—Block plan of large combustion of houses.
Scale, $\frac{1}{40}$ inch = 1 foot.

A	Span	Orchard House.
B	Lean-to	Peach House.
C	,, ...	Muscat House.
D	,, ...	Late Vinery.
E	Span	Plant House.
F	Lean-to	Early Vinery.
G	,, ...	Orchid House.
H	,, ...	Stove House.
J	Span	Green House.
K L M	Three-quarter span	Melons, Cucumbers, &c.
N O P	,, ,, ...	Pines, &c.
Q R S	Pits	Bedding Stuff, &c.
T U V	,, ...	,, ,,

Boiler-House, Potting-Shed, Mushroom-House, Gardener's Office, &c., &c., at back of wall.

Fig. 40.—Perspective view of range of green-houses, &c.

This was a combination designed by the author for W. H. Stone, Esq., of Lea Park, Godalming, and (with some modifications) recently carried out. It will be seen that a wall has against it a range, consisting of a central span-house, with three lean-tos on each side of it, the whole flanked by two spans. At the back of the range are boiler-house and various offices. In front are two ranges of narrow three-quarter span-houses, and, in front of these, hot and cold pits. The various uses to which the houses may be put is sufficiently indicated by the plan. Fig. 40 is a perspective view of a part of a combination of this character.

The centre house of a large range is frequently constructed as a show-house, in which case it breaks up the long lines of plain work, and affords a relief to the monotony of low-fronted growing-houses. For producing ordinary plants for the market, a favourite plan adopted by nurserymen is to build long parallel rows of low span-houses, each house about ten or eleven feet wide, having a walk up the centre and flat staging on each side.

SHOW-HOUSES.

CONSERVATORIES.

A SATISFACTORY treatment of conservatories from both the horticultural and architectural points of view is rather difficult. Hitherto the horticultural interest has been paramount, and while great attention has been devoted to, and a firm grasp obtained of the remaining portions of a dwelling-house by architects, they have, with very few exceptions, allowed the conservatory almost to escape their notice. The result is that the conservatory is frequently a hideous excrescence upon the dwelling-house.

An intelligent consideration of the subject in all its bearings, local as well as general, will usually help to remove many difficulties in the way of determining the most effective and efficient conservatory. As it will be found that each case will require to be treated on its own merits, general indications only can be given here.

HORTICULTURAL FEATURES OF CONSERVATORIES.

A conservatory is generally attached to a dwelling-house, and used for showing plants in contradistinction to growing them. Therefore the same conditions do not necessarily apply to conservatories as to growing-houses. Chiefly in consequence of the usual greater height of the former, and the difference between the constructional requirements of the former and those of the latter, it is always advisable to keep the two functions of showing and growing quite distinct; unless the establishment be so small that one house must suffice for both.

In growing-houses, plants should be conveniently near the glass, and therefore artificial supports to the pots are required. In show-houses, neither supports nor pots should be prominent. In growing-houses, plants should occupy the maximum available space. In show-houses, the space for plants should be subsidiary to the space devoted to the promenade. In growing-houses monotony may be almost necessary. In show-houses, artistic irregularity becomes a virtue. In most conservatories it is not only impossible to grow plants, but even to retain them in good condition for any length of time. Therefore growing-houses and conservatories should not only be kept distinct, but the former should be employed as feeders to the latter.

ARCHITECTURAL FEATURES OF CONSERVATORIES.

We will strike the key-note to the effective treatment of a conservatory by stating that until it is regarded not so much as a mere store-house for plants and flowers, but as a floral apartment—an addition to the reception-rooms in fact—its functions will not be properly developed, nor its uses adequately acknowledged.

Whether the conservatory is built at the same time as, or subsequently to the dwelling-house, it is essential that the architecture of the former should harmonize with that of the latter. This is easier to say than to do, for to treat glass architecturally requires great care. It is essential that architectural "emphasis" be given to the conservatory, and at the same time that the glass-work form an auxiliary complement to the remainder of the dwelling-house. Sufficient interest should be excited by the broad lines of a conservatory without the employment of fussy detail or meretricious ornament. The universal art canon—"Ornament the construction, never construct the ornament," should not be forgotten. Architectural features should balance the pure glass-work, and a mean should be aimed at between the extremes of too substantial and too "wiry" a character. While treating a conservatory architecturally, especially as regards the construction of the interior, the main object for which it is built—the exhibition of plants and flowers—must not be lost sight of.

It is not to be supposed that art, as applied to conservatories and architecture, necessarily means great expense. On the contrary, art in its truest highest sense, is not incompatible with moderate prices. The frontispiece will illustrate this. Upon reference, it will be seen that the conservatory depicted chiefly relies for its exterior effect upon well-balanced proportions and simple lines. The interior effect is produced, so far as the building proper is concerned, by a roof which forms with the horizontal an angle of 30°, in order that one pattern thrice repeated may produce a perfectly semicircular rib at each principal. The repetition of this rib in perspective is a very pleasing feature, and yet forms an integral portion of the construction. Such a house can obviously be produced at a very moderate cost. The frontispiece, Plates XLI., XLII., and XLIII., and Figs. 46 and 47, designed and drawn for the author by Geo. Sherrin, will serve to illustrate the various remarks on this subject. Fig. 48 illustrates a panel of tinted cathedral glass, lead glazed, suitable for the light above a transom in a conservatory.

INTERIOR TREATMENT OF CONSERVATORIES.

In conservatories, plants and flowers require to be exhibited in the most attractive and advantageous manner. To effect this, supports for pots and pots themselves should not be seen, but foliage and blossoms should be grouped naturally. Staging should be avoided unless it be very low and entirely hidden from sight. Beds and borders are always preferable to staging.

When possible, ample paved space for promenading should be provided inside a conservatory; not merely a paltry pathway, in which two people can scarcely walk abreast. No one, for instance, would dream of occupying, by furniture, the whole of the space in a reception-room, except a small

FIG. 44.—Marble mosaic pavement, designed by Burke & Co.
Scale, $\frac{1}{4}$ inch = 1 foot.

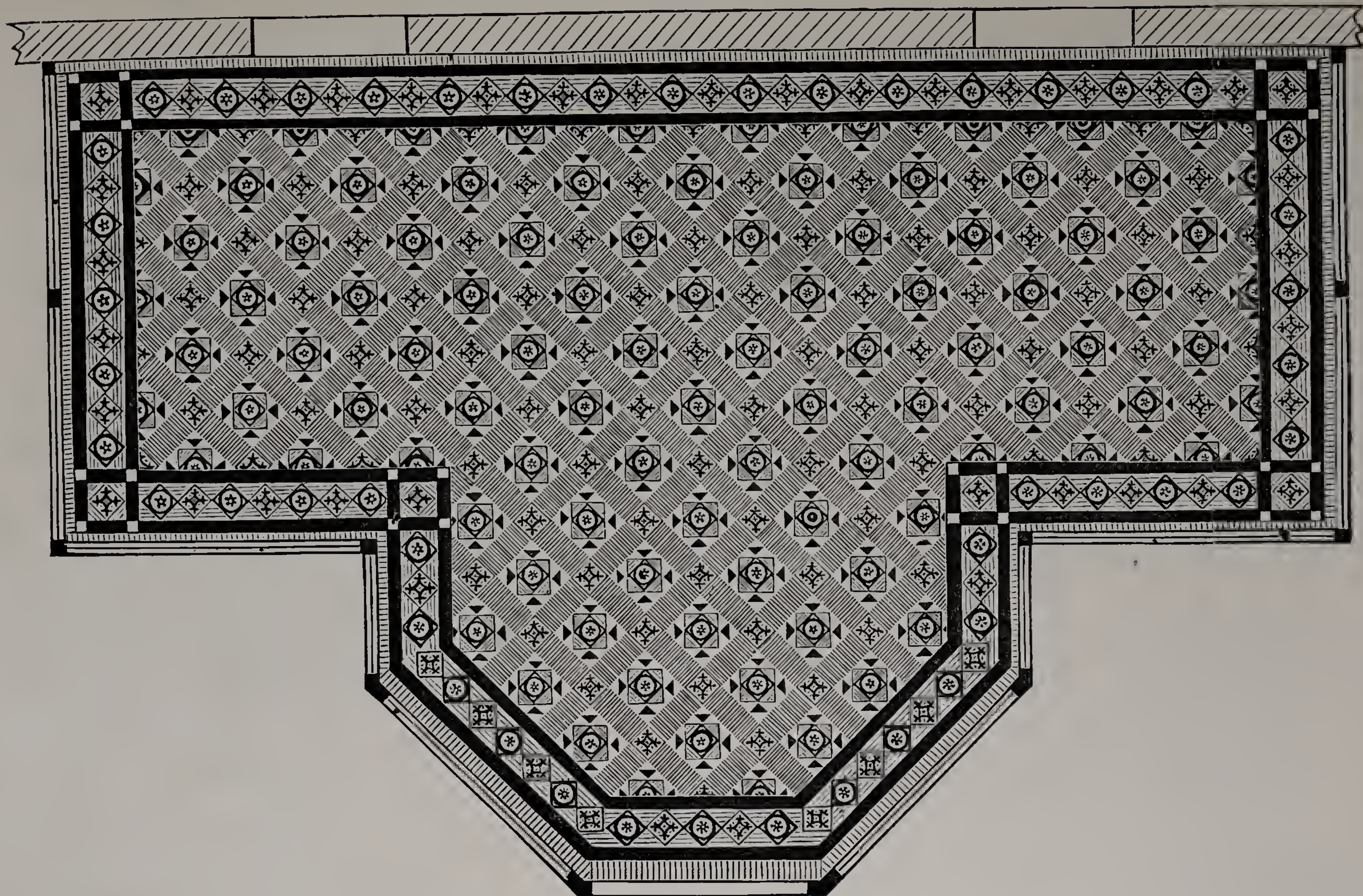


FIG. 45.—Tile pavement, designed by Minton, Hollins & Co.
Scale, ¼ inch = 1 foot.

pathway round an enormous central table. Of all materials used for paving, marble mosaic and tiles (see Figs. 44 and 45, both of which were specially designed and drawn for the author by the firms named) are the most popular and artistic.

FIG. 46.—Exterior view of conservatory.

A small table and a few chairs may sometimes be judiciously placed in a conservatory. Cane or bamboo furniture is very suitable, as these materials are not affected by damp. Where the size and proportions of the building will permit, sculpture and (or) a fountain may be advisable. Harsh vertical lines may be softened by creepers trained in a natural and graceful manner; and hanging baskets of drooping foliage may be used to vary the monotony of rigid roof lines. Walls, which would otherwise be ugly, may be covered by wood trellis, made, for ease in removal, repair, cleaning, and painting, in conveniently sized panels of either plain or geometric designs. Against such trellis, creeping plants and flowers may be trained. It is not necessary that such creepers should be specimen plants. On the contrary, the most suitable plant or creeper is one which will grow in the most natural manner without requiring much attention.

If gas be used in a conservatory, then a burner such as that described in article "Lighting" may be encased in an artistic lamp. In addition to the ordinary hot-water apparatus, an open fire-place, formed principally of tiles, may frequently be an elegant feature. To shade large vertical sashes, curtains made of South African plaited fine grass may be hung on brass rods. Such curtains are light, look artistic, hang gracefully, and are not affected by damp or sun. Mats of a similar character may be advantageously thrown down here and there. A parrot on a stand (a live one, not a china parrot), one or two japanese birdcages, an aviary (not a mere cage, but formed in the construction by a recess or alcove), or even a little old china, may often be introduced with taste. In this manner, by a judicious combination of art with nature, the beauties of plant life may be actually increased, and the conservatory be rendered an apartment to use and enjoy, instead of a place merely to walk into, and then walk out of.

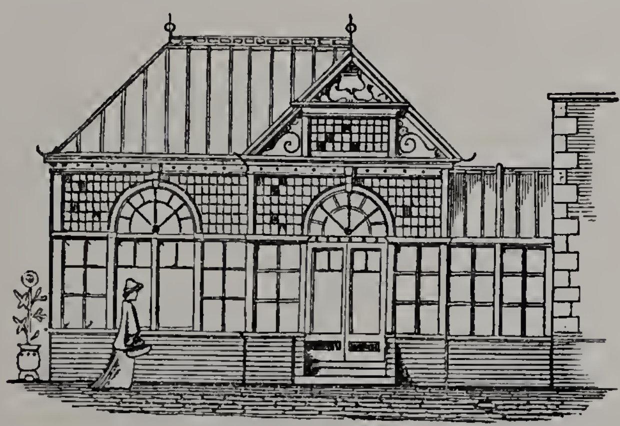


FIG. 47.—Exterior view of conservatory.

These notes on the exterior and interior artistic treatment of conservatories are written with the consciousness that the author is upsetting many preconceived notions. But he risks adverse criticism, and publishes his ideas, because he feels convinced that, when they are carefully considered, they will be found correct.

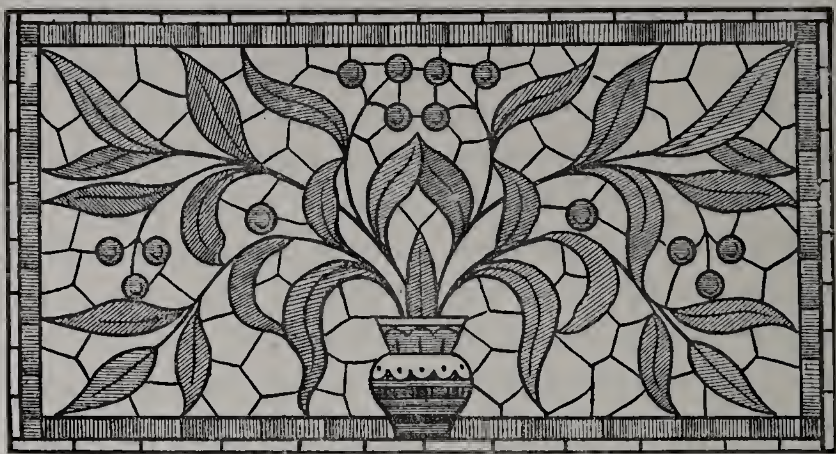


FIG. 48.—Panel of lead glazing, designed by W. Ramsey.
Scale, 1 inch = 1 foot.

CONSTRUCTIONAL TREATMENT OF CONSERVATORIES.

It is always better to look up to a conservatory than down to it, even if the difference between floor and ground levels be only one foot, or two steps. Taking the floor level as a datum line, the exterior brick or masonry wall need not be more than 2 feet high. The eaves may be 7 to 12 feet high, or even more, according to the other dimensions. Conservatories are usually attached to dwelling-houses, when doors generally communicate with the rooms as well as with the garden. Whenever practicable, the conservatory should only communicate with the dwelling-house by two doors in different planes; that is to say, by a short corridor with a door at each end: otherwise with a single door of communication, inconvenience may be experienced by the entrance of warm, moist air into the rooms. If, however, a single door only is possible, it should be made, by means of india-rubber or other suitable material, to seal the aperture hermetically, and thus prevent the transit of moist air. A conservatory floor should always be, practically, on the same level as the floor of the dwelling-house communicating with it; that is to say, although there may be a fall into the conservatory sufficient to receive a mat and to prevent water from running into the dwelling-house, this fall should never exceed about 2 inches. A decided step or two down into a conservatory is as objectionable as a serious change of levels between a hall and a dining-room. See article, "Paths."

Avoid valley gutters next the brick-work of a dwelling-house. Let the roof of a conservatory meet the dwelling-house, either at right angles (as in a span-house with its end against the brick-work) or at an upward inclination (as in a lean-to); never, if it can be avoided, at a downward inclination (as in a span-house, with its side against the brick-work).

Avoid a complicated roof. Simple gables can be treated very effectively. Hips are not objectionable, if they are judiciously introduced, and there be an obvious meaning in their use. Valleys, although they may not be next the brick-work, should be avoided unless the form of house render them necessary, and they either cross each other, or form some other symmetrical arrangement. There should be no straining for effect. No obvious gigantic internal effort should be necessary to support some useless external feature. The author has frequently seen a lantern or cupola introduced, which externally looked very pretty, but internally looked as if the whole brain-power of the designer had been exhausted in scheming the necessary supports. Anything in construction which is fussy, meretricious, irritating, totally unnecessary, or merely redundant, which offends the intelligence or excites the ridicule of the spectator, should be avoided.

Proper provision should be made for the chimney-flues and stoke-hole when the dwelling-house is built, even if the conservatory be not built at the same time. The cost of doing this is very insignificant. Neglect of foresight in this respect, however, is certain to entail heavy subsequent expenses.

WINTER GARDENS.

The functions of a winter garden are much the same as those of a large conservatory, with the exception that the former is usually much larger than the latter, is not generally attached to dwellings, and is, therefore, capable of distinct architectural treatment. Tropical plants and trees should be grown in winter gardens under conditions which approximate to nature.

Winter gardens, like other horticultural buildings, require as little obstruction to light as possible; therefore, while they must be built in a substantial manner, they must not be constructed of a material which unnecessarily excludes light. When a building is required for exhibition purposes, and interior floral decoration is only a subsidiary feature, it is often necessary that the materials, exclusive of perhaps the roof, should be of brick or stone. But when a winter garden or palm house is the primary object for which a building is erected, the skeleton framework should be constructed of iron, and filled in with glass. The heating, vaporizing, shading, &c., is carried out on the same principles as for other horticultural buildings. Details of designs for winter gardens can scarcely be treated here, but it may be remarked, in a general manner, that for their effective architectural treatment, broad lines, and large radius, flowing curves, rather than ornamental details, must be relied upon.

GARDEN FRAMES, ETC.

THESE are the simplest of garden structures, and their forms are so well known that very little regarding them requires to be said here.

GARDEN FRAMES.

The most usual size is about 8 feet long and 6 feet wide, thus :—

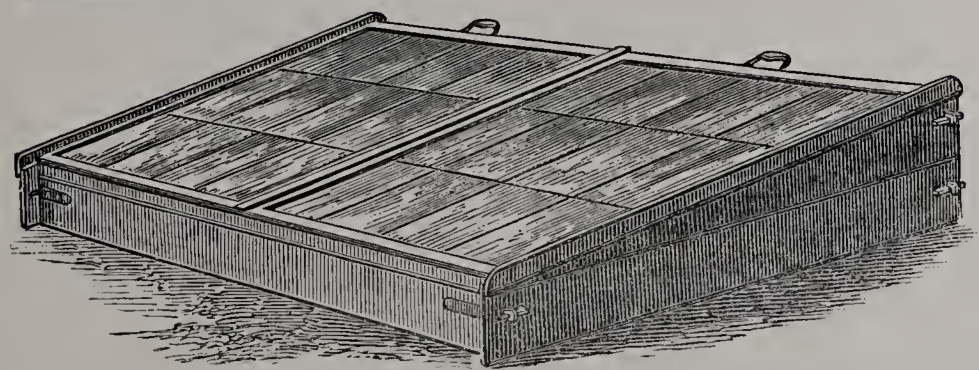


FIG. 49.—Two light cucumber or melon frame.

The height in front is about 13 inches, and at back 16 inches. The width of the frame forms the length of the lights, which are found convenient to handle when about 4 feet wide each. At every 4 feet, therefore, there will be a ⊥ moulded bar, upon which the sides of two adjoining lights will slide. In this way one set of frames may consist of one, two, three, or, in fact, any number of lights; the two ends being filled up with wood-work, and a partition or partitions of wood being placed, if necessary, at any bar. The figure on page 71 shows front, back and sides of wood, which is only advantageous if each set of frames consists of not more than three lights; if the frames must be portable; or if they require to be stored away during any part of the year. In the latter cases the wood-work sides should be fastened by iron straps and pins, rather than by ordinary mortices and tenons, for ease in packing, &c. This wood-work, as it comes in contact

FIG. 50.—Perspective view of Dennis & Co.'s registered plant frames.

with the soil or bed, may advantageously be treated by some of the preservative processes mentioned in the article "Timber."

PITS.

When garden frames, however, can always be used in one spot, and the space occupied by them is never required for any other purpose, especially when any long length of them has to be constructed, it is better to build the front, back, ends, and any partitions, of brick instead of wood-work. In this case, only the plates, bars, and lights are of wood and glass, and the whole structure is more durable and substantial. Frames constructed in this way are usually called pits. Frequently a row of these frames or pits are built against a green-house, the outer wall of which forms one side of the pits. This arrangement economizes space and brick-work, and sometimes heat, by allowing openings to be made in the wall between pit and

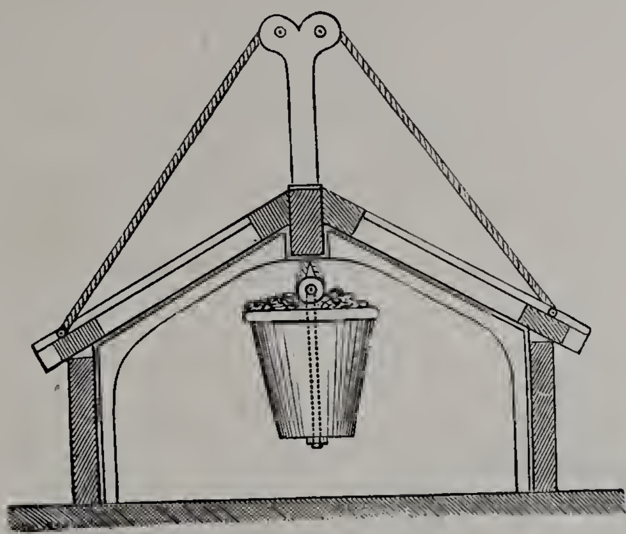


FIG. 51.—Transverse section of Dennis & Co.'s registered plant frame.

green-house, provided the latter has sufficient surplus heat. By this means also, hot-water pipes can easily be carried from the green-house into the pit without the necessity of sinking the pipes below the ground level.

On the whole, however, pits in the open are more advantageous, as the gardener can walk along the back as well as the front, and the contents of the pits are thus made more easily accessible; also, the lights can be slid up as well as down, thus (when the pits are heated by hot water) causing the air, when required, to pass over the pipes before touching the plants. This is not possible if the pits are built against a wall, and the hot-water pipes are only in the front.

When frames or pits are built against a green-house or wall, the lights can be opened by sliding them down. Or they may be hinged to the plate at back, and held up by a "ratchet quadrant set open." Or a horizontal bar may be fixed along the front, 5 or 6 feet above the ground, with a pulley on the bar over the centre of each light, carrying a cord and counter-balance weight. Or, in other cases, a hollow iron standard holding at the top of it a pulley, may be fixed at the back of each light, and the cord and counter-balance weight drop into the light. (See Figs. 50 and 51.) Or a wooden block, with several steps in it, thus:—

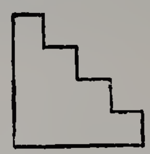


FIG. 52.—Block for ventilating pit lights.

may often be employed for holding open the lights at various heights. Such blocks are also useful for frames and pits built in the open, when ventilation is wanted without admitting rain or sliding the lights up or down. Some

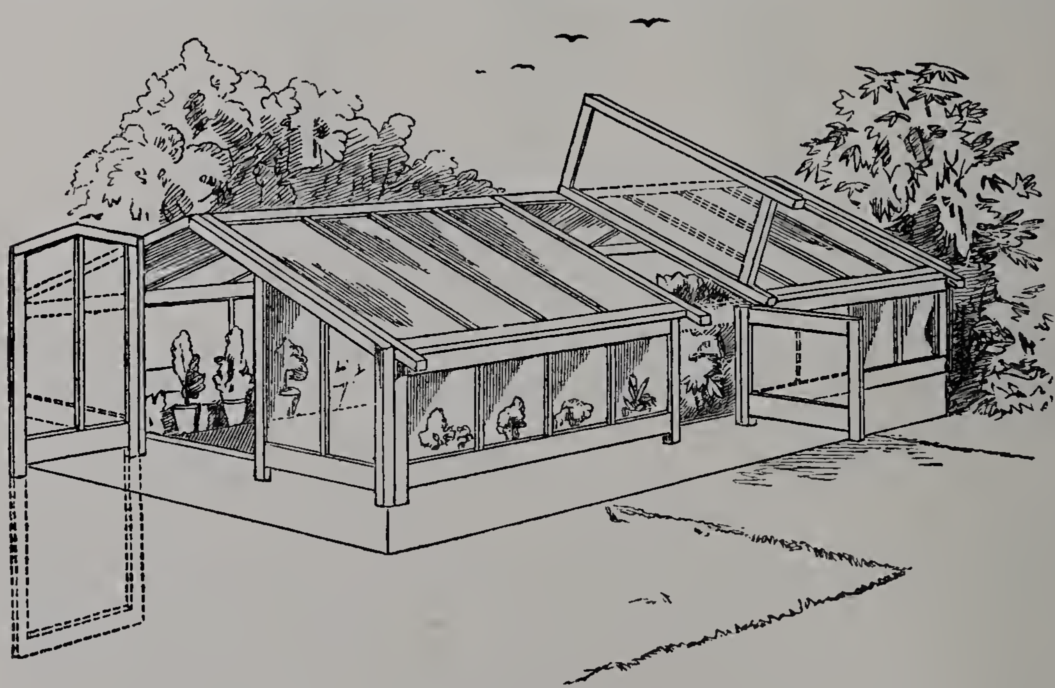


FIG. 53.—Perspective view of Dennis & Co.'s registered "Bijou" green-house.

makers hold the light open by fixing some studs to the sliding bars and placing the lights over one set of studs and under the next. Other makers employ ventilating contrivances such as different forms of ratchets, a simultaneous gear of rods, pinions, and racks, with the addition of lever-worked rising ridges, &c. But it should be noted that, above all things, simplicity ought to be aimed at, as in these small structures, which can so easily be manipulated by hand, complicated gearing occupies unnecessary space, harbours insects, gets entangled in the foliage, and wastes time.

Although Fig. 49 shows a lean-to frame, this form need not be adhered to if any other is considered preferable, especially if the frames are required for the protection of plants only. Figs. 50 and 51 show span frames, and Figs. 53 and 54 show a rather novel form of structure which (by having an

FIG. 54.—Transverse section of Dennis & Co.'s registered "Bijou" green-house.

entrance at the side and end, and somewhat sinking the path) at the price of a garden frame, provides what in a great many instances is an excellent substitute for a green-house.

PLANT PROTECTORS.

These are made of all sizes, and in all shapes, from small portable hand lights 12″ square and 6″ high at the sides, constructed of a light metal or wood framing, glazed all over, up to larger structures, which may be almost denominated garden frames or pits. Some of the small metal hand lights are made with tops separate from the sides. These may be canted a little, or removed altogether for ventilation; or if the whole be constructed in one framework, a piece of tile or brick under one or both sides will provide the necessary ventilation.

The following figure (Fig. 55)

FIG. 55.—Ground vinery.

shows a useful plant protector which has even been used as a "ground vinery." As shown, it is about 2′ 6″ wide and 15″ high. Mr. Rivers recommends it to be made in two lengths, each 7 feet long, and each having one wood end, making a "vinery" 14 feet long. It may be placed on any warm border, on the surface of the soil, and early vegetables, &c., requiring protection from frost, grown under it. The ventilation of the larger kinds of plant protectors can be similar to that of the frames, but as in the latter so in the former, simplicity is to be aimed at as much as possible.

SUBSIDIARY BUILDINGS.

ORDER and method cannot be too earnestly inculcated in horticultural as in all other operations. To carry out order and method, it is not only necessary to erect buildings in which to grow plants, flowers, and fruit; suitable places must be provided for preparation and storage. Whether these places shall be in one building, or a series of buildings, and what shall be the size and position of them, must be determined entirely by the extent of the establishment. They may form a series of buildings at the back of the wall of a range of houses. They may form an isolated block when there is no wall against which to place them. They may be all combined in one little shed a few feet square, when used in conjunction with a small green-house. Or they may form an imposing range of buildings, when applied to several hundred feet run of glass.

The following is a list of the principal subsidiary buildings :—

Potting-Shed, *Fruit-Room*, *Packing-Shed*, *Mushroom-House*, *Root-Store*, *Seed-Room*, *Fuel-Shed*, *Tool-House*, *Ice-House*, *Open Shed*, *Gardener's Office*, *Gardener's Apartments*, *W.C.*, *Manure-Pit*, *and Rubbish-Pit.* Besides these may be mentioned the *Summer-House.* We will comment upon them *seriatim.*

POTTING-SHED.

This is a most essential adjunct to horticultural buildings, however small. Green-houses can never look tidy if the operation of potting be performed in them. Sometimes, more for the sake of external appearance than anything else, part of a green-house is, by means of a partition, utilized as a potting-house. This, however, is not advantageous, as, although light is of course required in potting, a glass-house, unless well shaded by obscure glass and perhaps blinds in addition, would be too hot to work in. A potting-shed may very well be a brick or wood structure, fairly well lighted by a window or windows; having a door sufficiently wide to admit the passage of a barrow. Inside, in front of the window, may be a stout firm bench about 2 feet 6 inches high. Underneath the bench, or at the back, may be partitioned receptacles for mould, sand, pots, &c. The building may have a brick or concrete floor, and should be, subject to local circumstances, in as close proximity to the green-house as possible. The size will depend upon the amount of work to be done. In small establishments the same shed may be utilized as a tool and seed room. When a potting-shed is placed against the back wall of a range of houses, there may very well be a door of communication through the back wall in addition to the external door of entrance to potting-shed. For while the latter should be exclusively employed for carting in earth, pots, &c., the former is very useful for the easy transfer of plants to and from the green-house. This door of communication should not, if possible, be made in a house requiring great heat; but, where there is a choice, in the coolest house, as such a door, especially if it be frequently opened, would promote the escape of hot air and lower the temperature.

FRUIT-ROOM.

This is another very necessary adjunct to every garden; although in small and even in some large establishments, unused garrets are frequently employed as fruit-rooms. In order that fruit may be properly stored, the following conditions are required:—Darkness, a dry atmosphere, a cool, uniform temperature, but freedom from frost. Some gardeners consider a dry atmosphere is not necessary for keeping fruit, but if the fruit-room be dry, it can be made moist at a short notice if necessary, whilst the converse is not so easily effected. Air should freely circulate around the exterior and under the floor. There should be means for a thorough circulation of air in the interior when necessary. When ordinary means are of no avail, ventilation may often be promoted by means of a small outlet shaft having a gas jet in the lower part of it. There should also be a window or skylight, but provided with a wood shutter, either sliding or otherwise, so that perfect darkness may be ensured when required. The fruit store may be built of brick, but should have a double boarded roof, covered by tiles rather than slates, to form a non-conductor of heat. If fruit is warmer than its surrounding atmosphere, it is apt to shrivel; if colder, moisture is apt to condense upon it; therefore, vicissitudes of temperature should be avoided. There should be provision for keeping the frost out. The floor and walls may be boarded, and an air space of half an inch should be left between the walls and boarding. Tiers of shelves may be arranged round the room in such a manner that the fruit is easily accessible. The shelves may be constructed of small splines of wood chamfered on each of the upper edges, and having spaces between. (See Fig. 56.)

FIG. 56.—Transverse section of fruit shelf.

The fruit being laid in the hollow spaces formed. In this manner the fruit will have a small yet firm "bearing" on the shelf, will not be cut by sharp edges, and will allow the air to circulate freely round it. The width of the splines and distance they are fixed apart must be regulated by the size of fruit which is required to be stored. Early ripening sorts of fruit may, with advantage, be separated by a close partition from late sorts, as the exhalations from the former are prejudicial to the latter. At the earliest symptoms of decay fruit should be removed. Fruit should be isolated from each other. The section on the hygrometer should be referred to in reading the above remarks.

PACKING-SHED.

In establishments where not only a large amount of fruit and produce has to be stored, but also dispatched to a town house, or to other establishments, a packing-shed or room is a necessary adjunct to a fruit-room.

Packing fruit and storing it may be carried on in the same room or a separate place devoted to each, but in any case the localities of the two operations of packing and storing should not be far apart. A neat way of packing fruit for long distances is as follows:—Have some boxes made a convenient size, each box to hold several trays. These trays to be divided into compartments, and of the depth that is necessary to hold one layer of the fruit to be packed in them. The trays, when placed in the box, may have a layer of wadding between them or not, according to the description of fruit packed. When all the trays are in position, and the lid fastened down, the whole will be very compact and firm, and the fruit will not be liable to lateral displacement.

MUSHROOM-HOUSE.

This cannot be strictly called a subsidiary building, as it is essentially a growing-house. But as it is usually placed in the same category as the potting-shed, fruit-room, and other subsidiary buildings, chiefly because it requires no light, and can therefore be placed behind green-houses, &c., we include it here.

The requirements of a mushroom-house are:—Darkness, uniform temperature, and a hot, moist atmosphere.

A mushroom-house should, therefore, be built in much the same way as a fruit-room; with the exception that the floor should be of brick or other solid material unaffected by damp, not wood. There should be neither wood shelves nor wood-work round the walls. As in the fruit-room, so in the mushroom-house, the roof should be built of materials having small heat-conducting powers. A window or skylight, and closing shutter, should be provided. The length of a mushroom-house must be regulated by the quantity of produce required, but the width may be sufficient to allow for, say a 2′ 9″ path up the centre, and a 3′ 6″ bed on each side. An upright slate ledge 6″ to 9″ high may be fixed at each side of path to retain the materials in the bed. Space may be further utilized by fixing a number of slate shelves above the beds on each side. Each shelf to have an upright slate curb at the side next the path, and to be about 2′ 0″ to 3′ 6″ apart, from shelf to shelf. The materials of which the beds are composed will supply most of the heat required, but it will be advantageous to have, for a house of the width mentioned above, a flow and return 4″ pipe up the path. The top pipe should be provided with vaporizing troughs, so that moisture can be given to the atmosphere when required. Sudden changes of external temperature are prejudicial, and care should be taken to neutralize their effect inside the house. The mushroom-house may also be used to force rhubarb, seakale, chicory, &c.

ROOT-STORE.

The same remarks which were made in reference to the fruit-room will apply to the root-store, with the exception that the arrangement and construction of shelves need not be so elaborate, and the isolation need not be so complete for roots as for fruit. It is not often that a special house is built for roots, these being frequently stored in a dry, dark cellar.

SEED-ROOM.

The proper preservation of seeds is of the utmost importance, for however excellent seeds may be, their germinating power may easily be impaired or destroyed before the sowing time arrives. For most kind of seeds, the room should be dry, and means should be provided for excluding all external air when necessary. By Table XIX, it will be seen that water is at its greatest density at 39·2° Fahr., consequently this should be about the temperature at which (other things being equal) seeds should keep best; as the moisture contained in the seeds would expand, with possible detriment to the organs of the seeds, if the temperature rose much above, or fell much below this point. All seeds should be kept from the light. Most kitchen garden seeds can be preserved in canvas bags of various thicknesses. Some keep better in paper. Some, if closely packed in dry soil, preserve their vitality much better than in any other way. Some require to be kept in moist sand, or slightly damp moss; as, if allowed to become dry, they would lose their germinating power. These points, however, come within the special province of the gardener. Although seeds require to be preserved from light, this does not necessarily mean a dark room. In many cases a gardener's office does duty as a seed-room, and *vice versâ*. In whatever material seeds are enveloped, however, they should be placed in drawers, pigeon-holes, or compartments, for ease in reference and use.

FUEL-SHED.

This, it is needless to say, should be in close proximity to the boiler. If the boiler-house or stoke-hole be sufficiently large, one end of it may be utilized for an excellent fuel store by fixing a strong vertical transverse partition 3 feet high in front, and sloping upwards to the back. If this be carried out; or the stoke-hole be not large enough, and a separate fuel shed be built, it is advisable to have the fuel, if possible, on the same level as the feed-door of the boiler. For boilers, such as the ordinary saddles, which are fed from the bottom, the fuel store may be level with the stoke-hole floor. But for boilers, such as saddles with feeding shaft through the crown; or tubulars, which are fed from the top, the fuel should not be stored at a lower level than the top of boiler, or time will be unnecessarily wasted and trouble taken in throwing up the fuel when feeding the boiler. Although these remarks apply to all cases, it is not of so much importance to adhere to them in very small establishments as in large ones, in which the stoke-hole may be very deep, the vertical distance between the floor and feeding place great, and the amount of fuel to throw up large.

TOOL-HOUSE.

Whether in a separate special building, or whether in a building used for a combination of other purposes, it is very necessary that the tools, instruments, and small machines used in a garden should all have their proper places and protection. That, when not in use, they should be kept clean, goes without saying. The room in which they are kept should be well lighted, dry, airy, and under lock and key. The implements, such as spades, picks, hoes, rakes, forks, trowels, dibbers, brooms, rammers, not forgetting one or two wooden spatulas for cleaning spades, &c., may, at very slight expense, be kept in racks specially constructed to hold them. The tools such as hammers, mallets, pincers, pliers, various pruning and other knives, shears, scissors, axes, bills, chisels, saws, scythes, &c., may be hung in leather loops on the walls, taking care that they are symmetrically arranged, and have boarding, not bare walls, behind them, or they will be apt to rust by condensed moisture.

Places should also be reserved for instruments used in laying out grounds, such as lines and reels, measuring chain, rods, stakes, plummet, straight edge, ground compasses, levels, &c. The tool-house should also find storage space for lawn mower, garden engine, syringes, watering-pots, and such small implements, machines, &c., as require to be kept in a dry atmosphere and under lock and key. A bench, having on it wood and iron vices, and a grindstone, will be found very convenient; and storage space for pots, sieves, screens, fruit and other baskets, glass for repairs, &c., is also very necessary. Drawers or compartments, locked, may also be provided for a levelling instrument, surplus meteorological instruments, or those not always in use.

Finally, space should not be omitted for such miscellaneous articles as labels, spare foot scrapers, bell glasses, rat and mouse traps, nets, twine, wall shreds, nails, screws, canvas, wire of various kinds, &c., &c.

ICE-HOUSE.

As in many establishments the administration of the ice-house comes within the jurisdiction of the gardener, we may fairly include the ice-house in our list of subsidiary horticultural buildings. In order to melt a block of ce, heat must be abstracted from the surrounding atmosphere, or substances having a temperature of more than 32° Fahr. The heat thus abstracted is not shown, however, as sensible heat until the ice be melted. It is called the latent heat of liquefaction. When ice is surrounded by damp earth or water, it melts very much quicker than when surrounded by a dry atmosphere. The normal average temperature of the earth in Great Britain some distance below the surface, is about 47° Fahr. We therefore see that the conditions to fulfil in storing ice are—Isolation from the heat of the earth and atmosphere; good drainage, and dry surroundings. The ice-house should be protected from direct sun's rays, and have a northern aspect. A usual form is a conical pit (or sometimes that of an egg), sunk in the ground. The walls should be double, having an air space between them, with provision for ample ventilation when necessary, or keeping out currents of external air when too warm. If, when sunk in the ground, the pit cannot be drained, it should be built above ground, care being taken to throw up a good mound of earth all round it. Having made the bottom of the ice-house as dry as possible, a wooden grating, covered with good, sound straw or reeds, may be used to place the ice upon. Straw or reeds should also form an envelope between the ice and the walls. The whole should be covered with a thickly thatched straw roof, having overhanging eaves, so that rain will not be liable to run down the walls. Bruised, wet, or rotten straw should not be used, as it does not form so good a non-conductor of heat as sound, dry, unbroken straw or reeds. For every 112 lbs. of rough ice, it is usual to allow a space of about 6 cubic feet.

That the storage of ice is founded on the well-known principle of the interposition of a non-conducting envelope, is shown by the fact that a piece of ice can be longest preserved from melting by wrapping it in flannel; while our bodies are kept warm in the best manner by wrapping round them the same material. What keeps the heat from entering in the former, will keep the heat from escaping in the latter case. Ice may apparently be kept perfectly dry, and may yet visibly waste in bulk. This is in consequence of the outer surface melting, evaporating, and being carried away by currents of air. In some cases a little salt has been used in an ice-house, in order that, at the sacrifice of some of the ice, the rapid process of liquefaction may abstract any surplus heat which would tend to melt the remainder of the ice. This expedient, however, is never necessary, if the ice-house be properly built, so that the ice is well isolated from earth, water, and warm atmosphere. Very good dimensions for an ice pit are 12 to 15 feet diameter in the largest part, and 20 feet deep. The larger the bulk of ice, the longer does it take to melt.

OPEN SHED.

As in agricultural, so in horticultural buildings, an open shed is found very useful. There are many articles, which, while they require to be under cover, need protection from neither thieves nor external atmosphere. These articles are wheelbarrows, planks for wheeling soil, ladders, as well as portable frames, hand lights, &c., not actually in use.

GARDENER'S OFFICE.

Every man, whether he be a gardener or anything else, should endeavour to educate himself until he possess a methodical brain; when, his thoughts and ideas being in proper order, method and regularity must be stamped upon his actions. To promote and sustain these estimable qualities, a gardener, more especially if he be the chief of a large establishment, should be allowed the luxury of an office near his work. Not that this office need be a separate building. It may be merely space for a desk and a stool in one corner of the seed room. An office, nevertheless, of some kind or other, is necessary, in which he can formulate ideas, sketch carpet bedding, conduct correspondence, keep books of reference, file papers, keep accounts, receive instructions from his employer (who would, doubtless, prefer to give them on the spot than at the mansion, perhaps a mile away from the scene of operations) and give, quietly, to his subordinates, necessary hints and suggestions. A place, in fact, is required where he could, undisturbed, do many little things which could be so less conveniently done for instance in a cucumber-house, a vinery, on a manure heap, in the middle of a gravel path, or anywhere rather than in the proper place—a gardener's office.

GARDENER'S APARTMENTS.

Without giving him luxuries, which would unfit him for his work, a head gardener should be made as comfortable as possible. While it is necessary that he should have, near his work, an office, it is of no less a necessity that his living and sleeping apartments should not be at too great a distance from his work. This point should receive consideration, in case a gardener's cottage should not form part of the horticultural buildings. When, perhaps, the existence of thousands of pounds' worth of plants depends upon care in maintaining heat and other operations, it is not to be wondered that accommodation is provided near the houses; but in many instances, when so much value is not at stake, a gardener's comfort is forgotten. Whatever may be the faults of gardeners, they are usually devoted to their work;

are frequently required to undertake important responsibilities; are often blamed for the unfortunate results of climatic and other combinations quite beyond their control; and often receive less consideration for their comfort than they deserve.

While head gardeners should (and frequently do) receive every consideration, the comfort of the young gardeners, the assistants, and others should not be forgotten.

W. C.

This should be provided in the vicinity of all gardens, whether small or large.

MANURE AND RUBBISH PITS.

These are not always thought of in planning the horticultural buildings. Without them a garden, sooner or later, has a tendency to become untidy. While being in a convenient position for all purposes, they should be screened as much as possible from view. It is not always advisable to have a pit in the usual sense of the word. In many cases a dwarf retaining-wall is all that is necessary to prevent the rubbish or manure becoming spread about in an untidy manner before it is ready for its required purposes.

SUMMER-HOUSE.

Although not properly belonging to the subsidiary buildings for growing purposes, scarcely any garden is complete without a summer-house. The usual rustic thatched summer-house is the form generally adopted, but while it may be thought by some picturesque, those who have used it will be fully alive to its disadvantages. The annexed figure will very roughly illustrate a summer-house designed and made by the author, and used by him for several years. It is constructed of red deal, stained and varnished. The roof is of red tiles. It is glazed (above 2 feet from the floor) on three sides with, in the lower part, clear glass, and in the upper part tinted cathedral lead glazing. The back and floor is boarded. There is a seat at the back and two sides, and a wide rail, so that seated persons leaning will not break the glass. The interior is provided with a strong flap table and light curtains on sliding rods. Terra-cotta finials and cresting, of a scale to suit the structure, are fixed on the roof, but are not clearly shown in the illustration.

FIG. 57.—Improved summer-house.

Its advantages of utility are:—That it harbours no insects—That the interior can be kept as clean as an ordinary room—That, being screened by trees, and having a non-conducting roof, ample ventilation, and curtains, it is extremely cool in summer—That it can be entirely closed, and, with the aid of a lamp, is comparatively warm in winter—That it makes an excellent smoking-room, and, in fact, forms quite an attractive little country house. Architecturally, the combination of red tiles, lead glazing, and stained and varnished wood-work, imparts a very pleasing warmth and tone of colour to a garden, where rustic-work does not, for the reason that a rustic summer-house is neither a natural object growing, nor a decided architectural feature, but usually a lame attempt to make the latter a grotesque imitation of the former.

BRICK-WORK.

GENERAL NOTES.

IN London and the surrounding counties, brick-work is measured by the "rod" of $16\frac{1}{2}$ feet square, and reduced to a standard of $1\frac{1}{2}$ brick (14 inch work) in thickness; so that 272 superficial feet of $1\frac{1}{2}$ brick, or 306 cubic feet, or $11\frac{1}{3}$ cubic yards, equals 1 rod. In some parts of England brick-work is measured by the cubic yard. A good hard, well-burnt stock brick, such as is suitable for garden and green-house walls, measures $8\frac{3}{4}'' \times 4\frac{1}{4}'' \times 2\frac{3}{4}''$, and weighs about 6·81 lbs. each, or $60\frac{3}{4}$ cwt. per 1000, or 115 lbs. per cubic foot. Four courses, when laid, should usually measure 12 inches in height. Such bricks should not absorb more than about $\frac{1}{15}$ of their weight when placed in water (Molesworth), or $\frac{1}{5}$ after 24 hours soaking (Hurst).

No pillar or support of brick or stone should ever exceed in height 12 times its least thickness at the base, nor be loaded per foot super. with more than about 3 tons, if in cement, or 2 tons, if in mortar. Molesworth gives the useful data shown in Table X. to calculate the thickness of retaining-walls (such as terraces, sunk stoke-holes, &c.), supposing of course that such walls are not surcharged, but that the earth they retain is never raised above them.

TABLE X.—BRICK-WORK FOR RETAINING WALLS.

E = Weight of Earth-work per cube yard.
W = „ Wall „ „
H = Height of Wall.
T = Thickness of Wall at top.
T = H x Tabular number.

Batter of Wall.	E : W : : 4 : 5		E : W : : 1 : 1	
	Clay.	Sand.	Clay.	Sand.
1 in 4	·083	·029	·115	·054
1 „ 5	·122	·065	·155	·092
1 „ 6	·149	·092	·183	·118
1 „ 8	·184	·125	·218	·153
1 „ 12	·221	·160	·256	·189
Vertical.	·300	·239	·336	·267

Earth weighs from 77 to 125 lbs. per cubic foot.

CONCRETE.

One of the best compositions of concrete is the following :—Six parts clean shingle, screened gravel, or broken stone, 2 parts well-washed sharp sand, 1 part ground blue lias lime or (if for use in damp situations) best hydraulic lime or Portland cement. If the latter be used, not quite so much of it is necessary. The concrete, after being thoroughly mixed and thrown into position, should be well rammed before being allowed to set. In the composition of concrete much depends upon the size of gravel and the degree it is screened. Ordinary concrete weighs about 119 lbs.; concrete in cement about 137 lbs. per cubic foot.

HORTICULTURAL BRICK-WORK.

Walls in gardens, or against which green-houses are placed, may be of the following proportions :—

Table XI.—Dimensions of Brick Walls.

Height of Walls.	Thickness.	Piers at every 8 or 10 feet.
		″ ″
8 feet.	9″	14 by 4½
9 ,,	9″	14 ,, 4½
10 ,,	9″	14 ,, 4½
11 ,,	14″	18 ,, 4½
12 ,,	14″	18 ,, 4½
13 ,,	14″	18 ,, 4½
14 ,,	14″	18 ,, 4½

Walls above 12 feet high would, in all probability, only be built for green-houses to lean against, when, if no lateral thrust exists (as it should not), the green-houses would assist in supporting the wall, by helping to resist on that side the force of the wind. Piers at the back of a wall are advisable in all cases, although they might not be absolutely necessary if a green-house were placed on one side, and potting-sheds, offices, or out-houses on the other. All walls should have a damp course. The foundation of a garden wall should not be less than 2′ 6″ deep for a wall up to 10′ 0″ high, and 3′ 0″ deep for a wall above this height, with the base twice the thickness of the wall, by "sets off" of not more than 2¼″ each. Included in this depth of foundation, there should be 12″ to 18″ of good concrete. Much depends, however, upon the nature of the soil in deciding the depth of foundations. Firm gravel would not require so deep a base, and the concrete might be reduced or omitted.

For growing-houses, when vertical lights are used, the brick wall should be 9″ thick and 2′ 6″ high from floor to line of wood-plate ; when no vertical lights are used, this height may be increased to 4′ 0″. (See "Growing-houses.") As the weight of such houses is comparatively insignificant, the foundation need not have more than 1′ 0″ of brick-work below ground-line, with, if necessary, 1′ 0″ of concrete. When the houses are small, and the ground fairly solid, one set-off of 2¼″ on each side the base of wall is sufficient, and concrete may be omitted. If the houses are wider, there should be two similar sets-off on each side. If the ground is very treacherous, the width of base should be increased, and concrete added, so that the weight may be distributed over a larger area. For very small green-houses, 4½″ work is often sufficiently strong, although 9″ work forms a more effective non-conductor of heat. In very narrow forcing-houses, without vertical lights, it is sometimes found advisable to rise with 9″ work from ground to within 1′ 6″ or 2′ 0″ of plate, and then break back the wall to 4½″. (See Fig. 58.) The recess formed makes a good base for the hot-

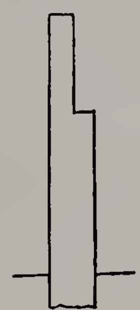


Fig. 58.—Section of Wall.
Scale, ¼ inch = 1 foot.

water pipes, which can, in this manner, be immediately in front of or underneath the ventilators in the brick-work. Vineries, or houses in which the roots require prepared borders, frequently have the walls built below the ground-line, on arches, in order that the roots can run either inside or outside the houses, and have a larger growing area. A very good method of obviating the necessity to build the front wall on arches, and suppressing a large amount of brick-work (which, especially if the house be narrow, forms a great obstruction in a border), is to support each mullion for 1′ 6″ or 2′ 0″ below the plate of front lights by pillars, filling in the space between the plate and the soil by slate slabs. (See Fig 59.) Of course the slate slabs are not required below the soil, or the roots would not be able to have free access to both sides of the border.

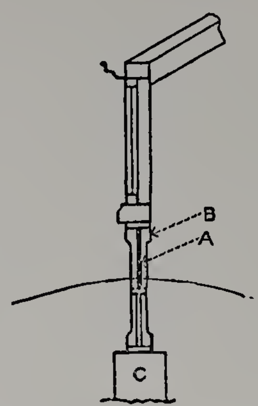


FIG. 59.—Section of front wall of house with inside and outside border. Scale, $\frac{1}{4}$ inch = 1 foot.
A Slate slab. *B* Iron pillar at each mullion. *C* Brick or concrete base.

Although no decided rule can be laid down regarding the brick-work of conservatories, it will seldom be found advisable to build their dwarf walls higher than 2 feet above the floor level. Large conservatories and winter gardens will, of course, require various modifications in thickness and height of walls to meet constructional and architectural requirements. The brick-work trenches for main hot-water pipes between the boiler and radiating surface may be rectangular in section, and of internal measurements, just large enough to enable the workman to lay the pipes conveniently and insulate the same by supporting them on bricks or stones at intervals. After a trench is completed, and the pipes fixed, tiles should be laid upon the trench, and the whole covered by gravel, earth, or whatever is required to be over the trench.

Walls in an exposed position may frequently with advantage be built hollow, the imprisoned air forming an excellent heat-arrester and radiation-preventer. Such walls may also be heated by pipes laid at the bottom of the hollow space, in cases where the wall-trees require artificial heat, and it is not proposed to cover them by glass-work.

TIMBER.

DESCRIPTION OF VARIOUS WOODS.

FOR purposes of horticultural building, the Onega, Archangel, or St. Petersburg deal may be considered very desirable wood. In some localities it is called yellow; in others, red deal. Oak is also used occasionally for parts of green-houses.

Northern or Baltic Pine (*Pinus Sylvestris*) is exported from the Prussian, Russian, Swedish, and Norwegian ports in the Baltic, and sent to England in the form of planks (11″ wide), deals (9″ wide), and battens (7″ wide), the thickness varying from 2 to 4 inches.

The red and yellow pines of North America (*Pinus rubra* and *P. mitis*) are simply varieties of the *Pinus Sylvestris;* the red is usually considered of finer grain, not so liable to shrink, and more durable than the yellow. They are seldom used, however, for external purposes.

The white pine of North America (*Pinus strobus*) is a very useful wood for some purposes, but not for horticultural work, as it is not very durable when exposed to the weather.

Pitch pine (*Pinus rigida*) is scarcely applicable to horticultural work, as it is much harder to work than the other pines, and its chief advantage consists in its rich veining when stained and varnished. Horticultural work is rarely, if ever, stained and varnished.

Fir (*Abies*) belongs to a distinct genera from the pines (*Pinus*), although builders and others often confound the two. Although white fir (*Abies excelsa*), from the same regions as Northern pine, and American white fir (*Abies alba*), or spruce, from Canada and New Brunswick, are not liable to so much shrinkage in seasoning as the pines, the former are often coarser, more knotty, liable to snap, and not so durable as the latter.

British oak (*Quercus pedunculata*) is also used occasionally for sills and plates, or those parts which serve to unite the general framework to the walls upon which it rests. As oak is more durable than the other woods, it may be used with advantage in just those positions where the material would be most liable to rot first. The *Quercus sessiliflora* is another species grown in England, and although rather softer and more liable to warp and become shaky in seasoning, is still nearly equal to the former. Baltic oak is also imported to a large extent from Dantzic, Stettin, and Memel.

The heartwood, which is the central portion of the trunk of a tree, technically known as *duramen*, is the only part of the tree which should be employed in horticultural work. Sapwood, which is the *alburnum* or exterior part of the tree next to the bark, and is that part through which the sap flows most freely, differs in colour from the heartwood, and should never be used. Knots should also be avoided as much as possible.

Scarcely anything tests the quality and seasoning of wood more than its use for hot-house purposes. On the outside it is exposed to the action of the atmosphere, and at various times soaking rains, frost, and scorching solar heat. On the inside of hot-houses the wood is exposed to atmosphere at a temperature sometimes 70° higher than the air outside, and frequently densely laden with a penetrating moisture. It is, therefore, imperatively necessary that the wood used should be thoroughly seasoned.

SEASONING.

Wood, in its "green" or natural state, more or less contains juices. These, if allowed to remain unchanged, would be very prejudicial to the wood, especially if it be immediately worked up and enveloped by some impervious material, such as paint. To dry these juices and render the preservation of the material more secure, the process of "seasoning" is carried out. This process consists, in fact, in drying the timber by stacking it, when sawn, into convenient sizes, in such a manner that the air can freely circulate, and protection from wet and vegetable growth be ensured. The mere moisture the wood absorbs from the air in dry weather is never sufficient to impair its durability. During this process the wood contracts, and if the seasoning be well carried out, is not liable to further shrinkage after it is worked up. But if the wood be used before it is sufficiently seasoned, or if it be allowed to absorb moisture, by being insufficiently protected from rain, and then immediately worked up, the wood contracts sooner or later. When this contraction takes place the different parts of the framing recede from each other, and cracks and crevices abound, which not only form a harbour for insects, but constitute receptacles for moisture with its rotting effect. But the "seasoning" may be efficient, and the wood perfectly dry when used, and yet it may be quite unfit for horticultural work. For if, in the course of seasoning, irregular shrinkage takes place, the tissues part in various places, and rifts and crevices, or "shakes," occur in the wood, to its great detriment, for the reasons already stated.

DECAY AND PRESERVATION.

Timber will decay from various causes. Those which interest us most are known as "wet rot" and "dry rot." The former is caused by a decomposition of the tissues, particularly of the sapwood, aided by moisture. The latter is caused by the growth of certain fungi which feed on the wood, and thus effect its disintegration. To prevent wet rot the natural moisture should be eliminated by proper seasoning, and the wood protected from all other moisture by coating it with some impervious substance, such as paint. The same means will tend to prevent dry rot, for moisture is most favourable to the growth of the fungus; but, singularly, an excess of moisture is frequently adverse to the development of this parasite. Again, if wood be in a condition to promote the growth of the dry-rot fungus, no coatings of paint will prevent the mycelium from penetrating to the interior of the wood. Once this takes place its destruction is certain. The fungus which usually attacks fir and pine is the *Merulius lachrymans*, differing from the species to which the common mushroom belongs, by having pores instead of gills. It is the pores (or gills) which hold the spores, reproducing the parent plant.

Independently of the ordinary seasoning, several processes are employed to destroy or prevent the growth of the dry-rot fungi. In general terms, all these processes consist in the impregnation of the timber with various substances, effected either by mere steeping or injected under pressure. The following are some of these processes :—

One of the most successful seems to consist in impregnating with the oil of tar, called creosote, from which the ammonia has been expelled. Albumen is coagulated, decomposition prevented, and the pores filled with a bituminous substance which excludes both air and moisture, and which is noxious to the lower forms of life.

"Burnettizing" is impregnating the timber with a solution of chloride of zinc. This renders the wood incombustible. It is considerably cheaper than creosote and is equally efficacious.

Another process consists in impregnating the timber with a solution of 1 part by weight of sulphate of copper to 100 parts water.

Another consists in immersing the timber in a saturated solution of corrosive sublimate (bichloride of mercury). This is called "kyanizing." The cost is rather high.

Payne's process is impregnating the wood, in a vacuum, with a strong solution of sulphate of iron, and afterwards forcing into the timber a solution of sulphate of lime, or any of the carbonate alkalies, so that the oxide of iron becomes insoluble. This process renders the wood incombustible. Further details of all the above are given in Hurst's Handbook.

These and other similar processes differ from mere seasoning in that the former involve—generally after seasoning is completed—the injection of certain substances ; the latter the drying of the juices without the introduction of any preservative substance.

For wood which has to come in actual contact with the soil, charring the exterior is frequently adopted and found an efficient preservative.

As may be conjectured, some of the most effectual of the above processes would be inapplicable for a greater part of the framework of horticultural buildings. Wood treated, for instance, with creosote could not be worked up, moulded, etc., in a satisfactory manner. Still, preservative processes are always useful for wood in contact with or partially or wholly buried in the earth, as park palings, posts, wood edging for paths and borders, lower parts of manure cucumber lights, wood framework over wells, etc.

For ordinary horticultural buildings, if the wood be thoroughly seasoned, not allowed to absorb moisture before or during the time it is worked, and kept well covered with paint, there is not much danger of its ultimate shrinkage or abnormal decay. (See "Paint," p. 110.)

GLASS.

THE PROPERTIES OF GLASS.

THE importance of glass in connection with horticultural buildings is, of course, so great, that a few scientific data in relation to it cannot be out of place.

From experiments carried out by Mariotte, Hooke, Melloni, De la Roche, but chiefly by Tyndall, it is evident :—That glass intercepts radiant heat to an appreciable extent—That its heat-transmitting power or diathermancy varies with the different sources of heat—That the higher the temperature of the radiating source, with the greater facility does the heat pass through the glass—That the thicker the glass, the greater is the amount of heat absorbed in transmission—That diathermancy does not seem to diminish in so great a ratio as the thickness increases—That inasmuch as luminous heat rays have a much shorter wave-length than non-luminous ones, the former are transmitted through glass with greater facility than the latter—That when bodies transmit heat very readily, they themselves are not heated to so great an extent. For instance, a window-pane is not much heated by the strongest sun's rays, but a glass screen held before a common fire stops most of the heat, and is itself heated thereby. The reason of this, of course, is that the greater proportion of the heat rays from a fire are non-luminous, and to these rays glass offers an obstruction.

The general chemical composition of glass is that of mixed silicate of potassium or sodium with silicates of calcium, lead, aluminium, etc. Ordinary window-glass is approximately a mixed silicate of sodium and calcium. English crown glass contains silicates of potassium and calcium.

Without going any deeper into the manufacture of glass than is necessary for our purpose, we may mention that the following are some of the kinds of glass used for glazing purposes.

VARIOUS DESCRIPTIONS OF GLASS.

Crown Glass. This is blown into large globes and opened out into circular flat tables. From being circular, and having a knob in the centre, it is more wasteful than, and does not admit of being cut into such large squares as sheet glass.

Sheet Glass is manufactured by being blown into long cylinders, or "muffs," then split down and flattened. This process, of course, enables the glass to be manufactured without knobs and in a rectangular form.

Plate Glass is either cast on iron tables for large squares, and polished, or, for smaller squares, blown into a cylinder and polished.

Patent Plate is another variety, not having so true a surface as plate, but quite as brilliant and much cheaper.

Rolled Plate (Hartley's) is a fluted glass used as semi-obscure glass for permanent shading, with corrugations varying from 20 to 10 to the inch.

Rough Plate is another semi-obscure glass, not polished, and bearing on one side the marks of the table. Rough Plate is also made fluted, in two kinds, one pattern 11, the other 4, flutes to the inch.

HORTICULTURAL GLASS.

The description of glass usually employed for horticultural purposes is English Sheet, 21 oz. to the square foot. The thinner quality, 15 oz. to the square foot, is sometimes used for the sake of cheapness, but will not so easily resist hail, and is much more liable to scorch plants than the 21 oz. Belgian Sheet glass is also occasionally employed on account of its cheapness, but being more speckled and wavy than, and not being so strong as the English Sheet, should not be used.

The thickness, theoretically, of English Sheet glass is :

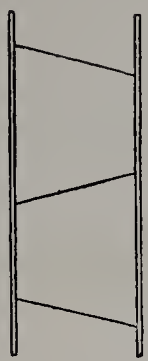
15 oz.	... ...	$\frac{1}{13}$ inch
21 ,,	... ...	$\frac{1}{10}$,,
26 ,,	... ...	$\frac{1}{8}$,,

The chief causes of "scorching" (concentration of the sun's rays) are bubbles of air and unmelted pieces, or what are called "stones." When the "metal" is melted in the pot, the clearest part rises to the surface, and is of the quality known as "Best." The next layer in the pot is taken to make the glass called "Seconds," the next layer "Thirds," the next "Fourths." Sometimes another layer, or even two, are utilised, which glass, however, is very coarse, and only used for very inferior work. The first layer, or "Best," is usually worked by more experienced men than the succeeding layers. Yellow glass is useful in preventing the development of the actinic rays, whilst violet glass transmits with ease the chemical rays. (See "Sun's Rays," p. 12, and "Inclination of Roofs," p. 18.)

We will say nothing about the use of coloured glass in conservatories. Although a man may have the legal right to smother his conservatory with red and blue paint and equally bright-coloured glass, we cannot concede that he has the moral right to insult as well as injure his plants and flowers by placing them in a building made so ridiculously hideous.

GLAZING WITH PUTTY.

The first point to be mentioned has reference to cutting the glass. Now, as the bars are usually vertical, or in the direction of the slope of roof, it is obvious that one pane of glass cannot be made to extend along the whole length of the sash-bar. To prevent the use of horizontal bars, it is customary to "lap" the glass. These laps should not be more than about $\frac{1}{4}$ inch in length, or an amount of moisture will be held by capillary attraction sufficient, in the case of frost, to break the glass. In addition to this, if the laps are any longer than specified, they may become unsightly in consequence of the retention of dirt. The lines in a roof or any part of a house formed by the laps should be continuous and regular. That is to say, suppose a lean-to roof have a 12-feet rafter, and it is intended to use panes of glass about 2 feet long, there should be five continuous and regular lines formed by the laps, equidistant from each other and from the ridge and gutter. If a span, octagon-ended, or other shaped roof meets this lean-to, the "lap" lines should still be carried round in the same horizontal planes. Several modes of cutting the glass have been suggested with the view of overcoming any disadvantage caused by retention and subsequent freezing of lap moisture. Figs. 60 and 61 show two of these suggestions.



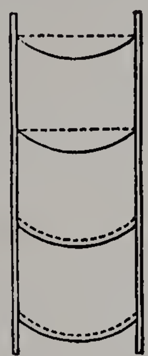


FIG. 60. Various modes of cutting glass. FIG. 61.

In the first the glass is cut alternately at an acute and an obtuse angle, and not lapped at all, but the edges of glass are supposed to "butt." The object desired is that no lap, and consequently, no capillary attraction shall exist, and that any moisture which may be inclined to drip through shall first run to one of the sash-bars. The impracticability of this arrangement is self obvious. The glass cannot always be cut to the same angle, when the panes will not butt along their whole width, an angular aperture will result, and heat will be rapidly lost. Further, unless the glass is cut at a very sharp angle, wet will still drip through from any part of the pane.

The second arrangement, Fig. 61, shows the glass cut with a curved end to each of the panes. The objects here are that wet shall run down the centre of the panes only, and accumulation of moisture, with drip from the laps, prevented. But it will be seen that if, while the top of a pane be cut horizontally, the bottom of the one above it be curved, as shown by dotted lines to the top panes, the lap will naturally form a segment of a circle, and irregular capillary attraction will result. There will then be a greater breadth of lap and more wet in the centre of the pane than elsewhere, and almost certain breakage by frost will ensue. This objection can be overcome to a certain extent, if, at the laps, the edges of both panes be cut to the same curve, as shown by dotted lines to the bottom panes. This, in practice, is difficult, for glass can easily be cut to receive at the edge a convex curve, but can only with great difficulty be cut to receive at the edge a concave curve. Even then there will always exist a tendency for irregular accumulation of water to take place at the laps. So far as the glass is concerned, the laps should certainly be horizontal.

The next point has reference to the putty, and where it should be placed. Owing to the trying atmospheric and solar conditions under which horticultural buildings exist, the putty is apt to harden, crack, peel off, lay bare and rot the wood, provide crevices for moisture and insects, and cause drip inside. To obviate this, many horticulturists have embedded the glass in putty, but allowed no top putty to be used, merely "sprigging," or holding down the glass with brads. This system may answer well for cucumber frames, small growing-houses, &c., but its appearance is by no means sightly, and it is, therefore, unsuitable for conservatories or houses which are built for appearance as well as use. All difficulties, however, will be avoided if the putty be properly made and properly used. If good boiled linseed oil (about nine parts) be mixed with tallow (about one part), and then thoroughly incorporated with whiting to the required consistency, the putty made will not be liable to harden and crack. The glass should be accurately cut and firmly embedded in the bottom putty, so that the latter forms a thin regular layer between the rabbet and the glass. The glass should be "sprigged" with copper tacks. The top putty should then be evenly and smoothly cut on, not too profusely, but sufficiently to form in section a right-angle triangle with a much smaller base than perpendicular, thus:

FIG. 62.—Vertical section of putty.

Having no burr or crevices left upon it. There will then be no liability for water to lodge, and the putty, while hard enough for practical purposes, will be sufficiently soft to be cut with a knife when repairs are necessary. It is essential that putty should not set too hard and crack, as well for iron as wood houses, more especially as the putty would probably be the only substance in the former to yield to the expansion and contraction of the iron and glass. The wood should be thoroughly painted both before and after glazing. (See p. 110.)

When ordinary putty becomes very hard, it may be softened for the purpose of easy removal by keeping it moist for a short time with caustic potash or soda; or if the putty be painted with nitric or muriatic acid, it will be softened in about an hour.

It has been frequently the custom to putty the laps, but although this makes a house easier to heat, and (if the laps be wide) sometimes saves breakage of glass, yet it is not only unsightly but increases in a roof the area of obscurity to the sun's rays.

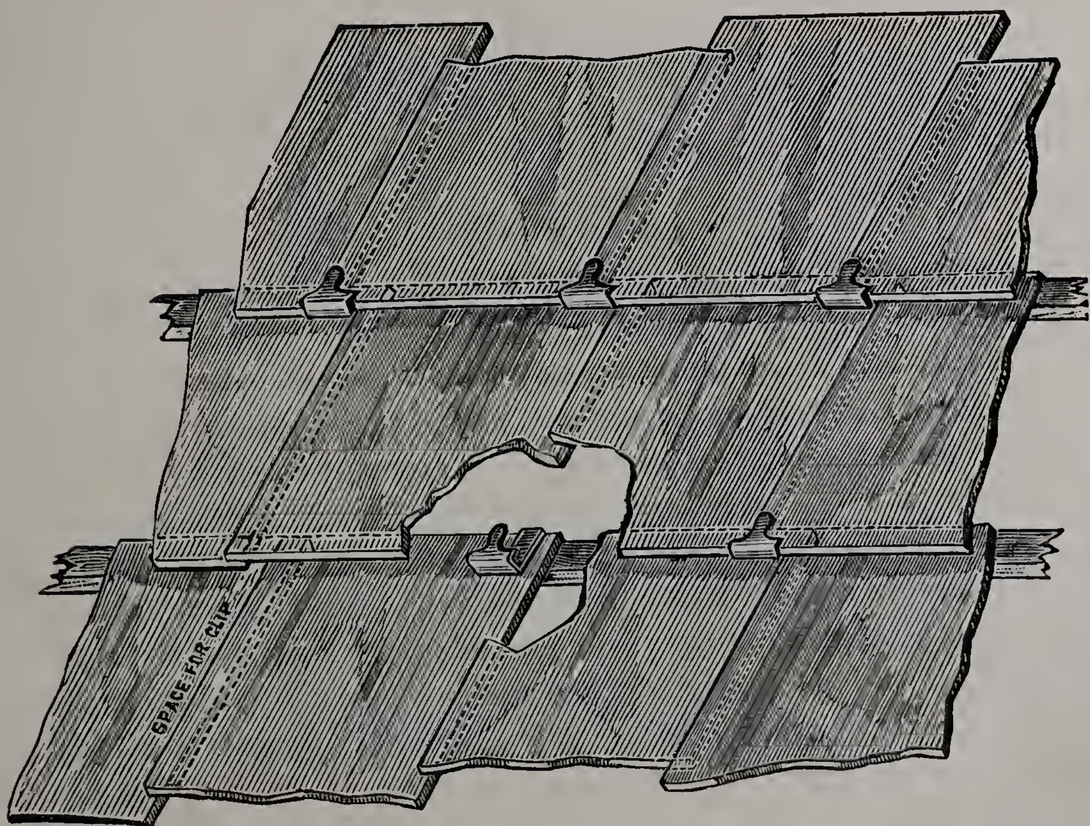


FIG. 63.—Helliwell's system of glazing.

MECHANICAL GLAZING.

A number of systems have been patented and introduced to obviate the use of putty. Amongst the principal are those invented by Helliwell, Johnson, Rendle, and Shelley.

Fig. 63 represents a portion of a roof glazed on Helliwell's system. Rafters are placed about 6 feet apart; to these are fixed horizontal glazing bars, serving to hold copper, brass, or zinc clips for the panes. In iron roofs the clips are bolted on to angle iron bars. For roofs of large area, where rolled or cast glass is proposed to be used in very large squares, Mr. Helliwell recommends his vertical bar glazing as most suitable. Fig. 64 shows a section through this vertical bar. The usual rafters and purlins

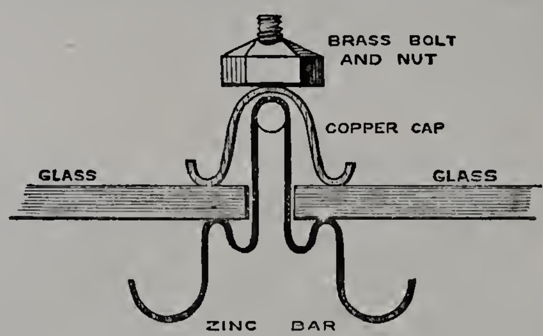


Fig. 64.—Section of Helliwell's vertical bar.

support a vertical zinc bar, which holds the glass. A copper cap, screwed to the bar by brass bolts and nuts, completes the glazing.

The patentee claims for his systems that:—They can be used on iron or wood roofs, circular or otherwise—Saving in wood-work effected—No putty required—No perishable material exposed—No outside painting necessary—Glass can be easily taken out, cleaned, and re-glazed—No breakage from expansion and contraction—No opening round the edge of the glass—No rattle or looseness of panes—No drip from condensation.

Johnson's system consists of compressible zinc (or copper, if considered desirable) glazing tubes, of which a section is shown by Fig. 65, clipped together in such a manner that elastic grooves are formed to receive the glass. At the foot of each glazing-tube the panes are secured by a brass clip, held in its position by a cotter or screw, so that it can easily be removed and the panes slid in or out as required.

The advantages claimed are :—Perfectly water-tight joint, without the use of putty—Expansion and contraction permitted, and breakage prevented—

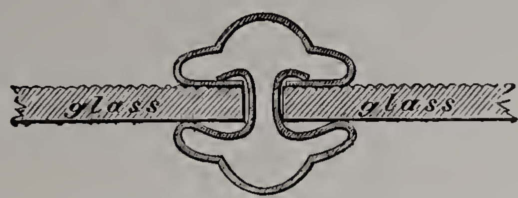


FIG. 65.—Section of Johnson's compressible glazing tube.

No paint either inside or outside required—Great durability—Little liability to get out of order—Comparatively no obstruction to light and heat—No bent glass used—Lighter and neater external appearance.

Rendle's systems are as follows :—

First.—Horizontal zinc or copper bars are fixed to purlins supported by rafters in the usual way. These bars have different sections. Those next the ridge have an inverted **U** section; intermediate bars have a long **S** section, of which the upper member is continued in a straight line to the bottom of the letter; the lower bars have a **J** section. These bars have holes in them, and pieces cut out of their lower edge at intervals, to allow the water to escape. The glass is cut so that by pushing the upper edge into the bar as far as it will go, the lower edge will be able to fall into its bar. The glass is lapped vertically from 1 inch to 1½ inch.

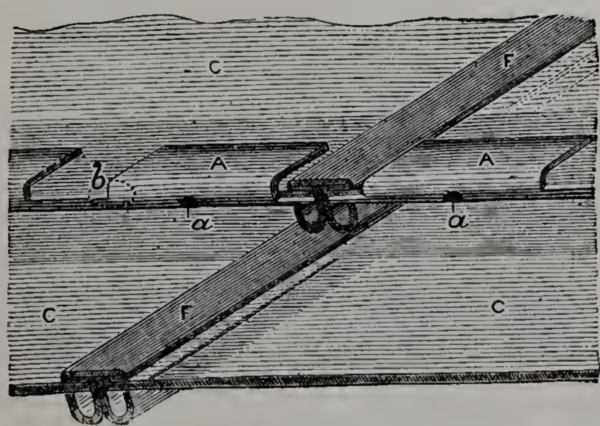


FIG. 66.—Rendle's "Combination" system of glazing.

A Horizontal bar. *C* Glass. *F* Vertical bar.

a b Holes for allowing moisture to pass to the outside of the panes below.

Second.—Another system is called the "Combination." This is similar to the last, except at the vertical joints. Instead of lapping the glass, a vertical bar is used. (See Fig. 66.) This bar is constructed with grooves, into which the glass is placed. The channels in the bar carry off any moisture condensed inside the panes to the outside of the pane below. The bar also forms a strong bearing for the glass, so that panes may be used as long as 4 feet. This system is recommended by its inventor for flat or very exposed roofs, or where long glass is preferred.

Third.—Another system is called the "Acme." (See Fig. 67.) This

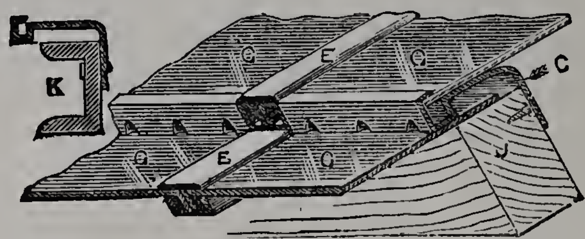


FIG. 67.—Rendle's "Acme" system of glazing.

C Horizontal bar. *E* Vertical bar. *G* Glass. *J* Wood purlin. *K* Channel iron purlin dispensing with wood.

system differs from the last in the following points:—The lap is greater on account of the clip securing the glass being narrower. There being no clips, the rain runs away freely. The channels of the vertical bars are square, thus filling the slot in the horizontal bar, and giving greater strength to the glass. The purlins are narrower. A channel iron purlin can be used instead of wood.

Mr. Rendle claims for his systems the following advantages:—Saving of from 80 to 90 per cent. in maintenance and repairs—No breakage from contraction or expansion, as glass has "play" in every direction—No breakage from vibration, caused by heavy winds or passing trains—Glass inserted in one-fourth the time of the old plan, and instantly replaced—No drip from condensed steam—Putty, cement, felt, &c., entirely dispensed with—Circular roofs glazed with straight panes of glass.

Shelley's system consists of chilled cast-iron bars, grooved to allow the glass to slide in flap. (See Figs. 68 and 69.) In the grooves at intervals, stops are provided, which, when the glass is slid past them into its place, prevent it from being blown or coming out of the grooves. Between the upper edge of groove and the glass, vulcanite cord is placed to hold the glass with elastic rigidity. Each bar has ears cast on it to screw it to the purlins of roof; and at the lower end of the bar is a shoulder to hold

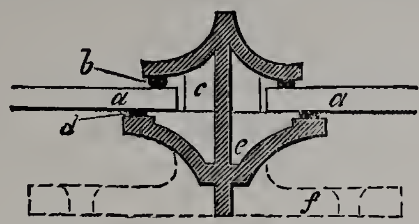


FIG. 68.—Section of Shelley's glazing bar.

a a Glass. *b* Vulcanite (moveable). *c* Patent stop. *d* Vulcanite fixed to bar *e* Groove to carry away moisture. *f* Lugs to secure bar to roof.

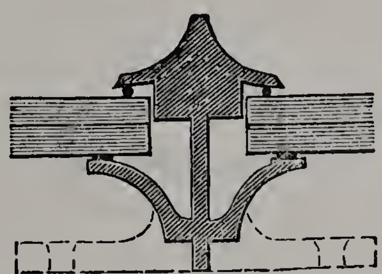


FIG. 69.—Section of Shelley's glazing bar showing laps of glass.

the bottom sheet of glass and prevent it slipping on to the portion of roof below it or the gutters. For renewal, repairs, or unglazing, each sheet of glass must be raised in its groove, out of the influence of the stop, and moved laterally, so that each edge alternately may be liberated. Unless, however, a knowledge of the properties of the stop is possessed, glass cannot easily be removed. No rafters are necessary, but purlins require to be provided about 6 feet apart.

The patentee claims for his system the following advantages:—No perishable material exposed to atmospheric or other influences—Use of wood may be entirely dispensed with—Purlins only required about 8 feet apart—Glazing easy and quick—Putty dispensed with—Painting optional—Glass cannot be blown out—Unglazing difficult, unless the system is known, rendering a roof to a certain extent burglar-proof—No breakage can result from expansion or contraction—Equally effective at any angle—No zinc used—Circular roofs can be glazed with straight glass.

Although mechanical glazing may be advantageously carried out for the roofs of railway stations, exhibitions, baths, markets, weaving sheds, warehouses, &c., it will be found on consideration that for horticultural growing-houses no system yet invented can supersede putty glazing. Taken as a whole, the world is intensely conservative, and any system, however good, would have a difficulty in superseding existing systems, however bad. But independently of this, the fact that glazing with putty still holds its own in horticultural buildings, is because no other system has yet fulfilled, to so great an extent, the requirements of horticulturists. In glazing without putty, one of two courses must be adopted. Either the glass must come in contact with metal, and a certain amount of "play" allowed, or glass must come in contact with some yielding substance. In the first case, hot air has abundant opportunities for escape; houses cannot be properly fumigated; crevices for the retention of water by capillary attraction abound; subsequent freezing of this water and constant breakage of glass are liable; and the same crevices which hold water can also harbour insects. In the second case, even if the elastic substance employed be sufficiently well adjusted to hermetically seal the roof, the peculiarly trying atmospheric influences to which hot-houses are subject, render liable the speedy destruction of the elastic medium, when the expense and trouble of renewal will probably be far greater than with a puttied roof.

It is true that in most of the systems of artificial glazing the greater part of the material of which the bars, rafters, purlins, &c., is composed, is inside the house. This, however, may be a positive disadvantage, if, in consequence of it, the possibility is precluded of placing a board or ladder on the outside of the roof. It may not always be possible to glaze a house from the inside, especially in the case of the renewal of glass in a vinery, in which the vines are near the glass, and cover the whole of the roof. One of the chief objects of mechanical glazing is that the glass may be rapidly and easily taken in and out. This, again, may be a positive disadvantage, for in such a case a child may in five minutes take out a few panes, walk into a house, take some valuable fruit, walk out and re-glaze, in spite of locks and other precautions. Some of the systems of mechanical glazing are more costly than glazing with putty. Some require very wide laps to the glass. Now, a wide lap increases the liability to breakage by facilitating the accumulation and retention of moisture, forms a receptacle for dirt, looks bad, and is apt to cause burning of the plants.

Horticulturists would be exceedingly glad if the necessity for putty glazing could be obviated; but a careful watching and lengthened experience of the various systems of mechanical glazing have confirmed the conviction that if proper materials be used, and the process carried out carefully, no system is better adapted for horticultural buildings for growing purposes than glazing with putty.

PAINT.

IN the article on "Timber" and section on "Iron *v.* Wood-houses," it is remarked that when wood is in a fit state for use and is worked up into the form in which it will be required, it should be preserved from the effect of moisture by being coated with some impervious substance. The substance most generally employed for this purpose is "paint."

Paint is a mucilaginous substance which acquires hardness by exposure to the air. White-lead, the principal basis of all paints, is carbonate of lead generally containing hydrated oxide of lead. Zinc white is another metallic paint used for light colours ; it possesses, however, less body than white-lead.

Several preparations are employed as paint. Carson's anti-corrosion paint has for a base (excluding colouring matter), ground glass bottles, scoriæ from lead works, and burnt oyster shells. Besides this, there are oxide of iron paint, silicate of iron paint, &c., &c. The best vehicle for the distribution of paint is good linseed oil. For outside work, turpentine should be avoided as much as possible, as turpentine is more susceptible to water than oil. If the work is required to be white, however, and white-lead is used, a small proportion of vegetable black is frequently added. Strange as it may seem, this prevents the discoloured appearance which paint would have if composed of white-lead and oil only. A small proportion of driers (litharge) causes the paint to dry harder and quicker. When oil gives way to turpentine (usually in a finishing inside coat only) work is said to be "flatted." Only irregular reflection of light takes place from such flatted surface.

No paint should be applied until the wood is well seasoned and quite dry. So soon as it is worked to the required form, it should be knotted, primed, and stopped. The former consists in "killing" the knots by the application, when hot, of a composition which may be made of equal parts of red-lead and glue, mixed with water. A composition called "Patent Knotting," sold ready for use, is sometimes used. "Priming" consists of painting with white and a little red-lead mixed thin with linseed oil. After stopping, or making good defects and holes with putty, and after another coat of rather stronger priming colour is used, the work may be fixed ready for glazing. On no account should the work, prepared at the shop, be sent to its destination without priming. Although it may be protected from rain, moisture may condense on the surface of the wood, enter the tissue, be kept there when painted, be prevented from evaporating, and finally effect, by rotting, the destruction of the material. In any case, the under side of wood plates or of any wood-work touching the brick-work, should be well painted before being fixed. After the glass is put in, two coats of good oil-colour should be applied. The last coat may very well contain boiled as well as unboiled linseed oil, each in about equal proportions. The best finishing colours for horticultural work are stone colour and white.

Grained or stained and varnished work is objectionable from a horticultural point of view, although either may be necessary in order to meet the architectural requirements of a flower-room or corridor; when, in fact, the plants are subsidiary to the architecture.

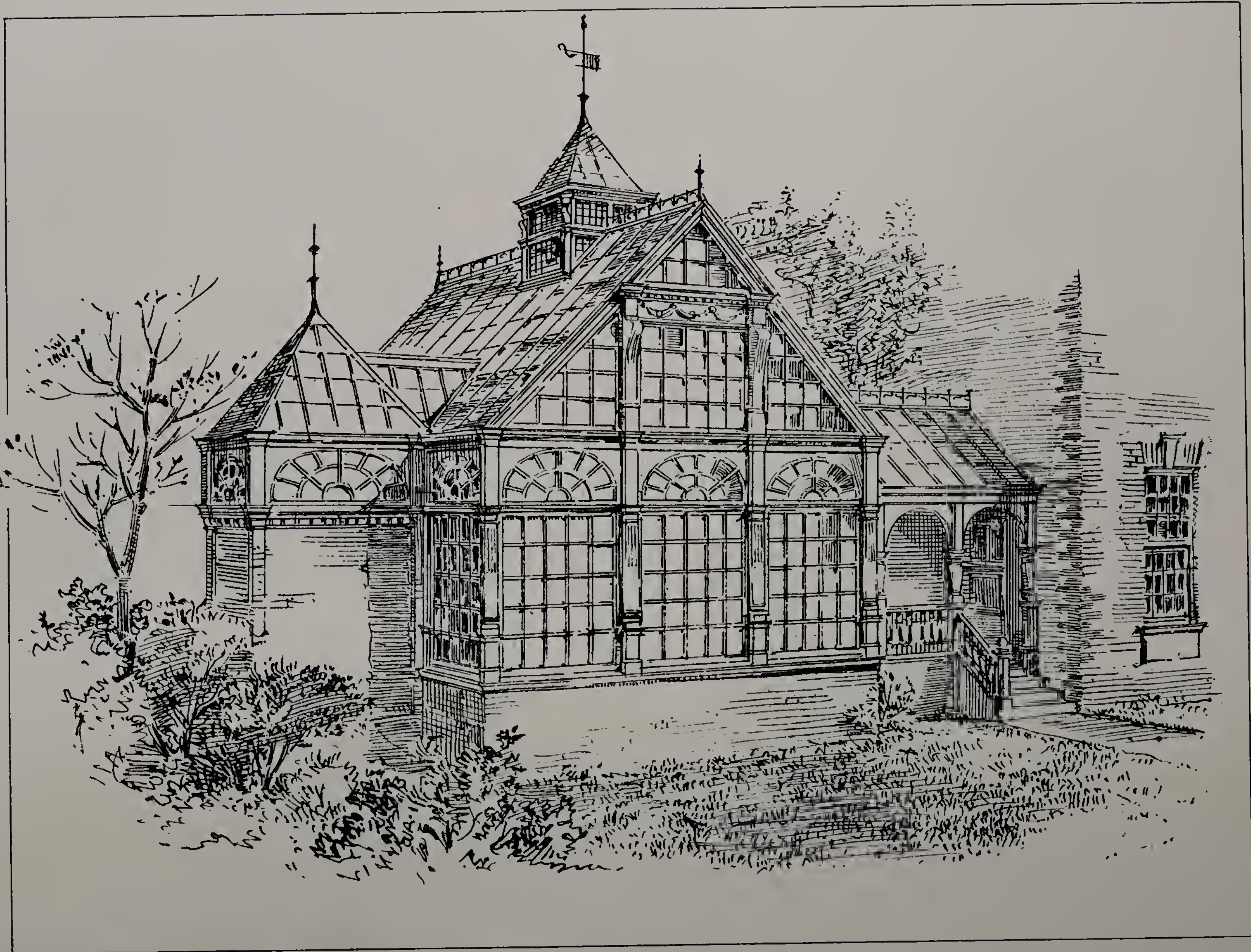
For interior work, flatted paint may look very well, especially as it is frequently considered that plants and flowers are shown to advantage when the wood or framework in close proximity to them, without having a shiny surface, has a surface which reflects, not absorbs, light; but it must always be borne in mind that flatted work is not suitable for a moist, hot atmosphere. It is not an uncommon thing to see mullions, sashes, and any ornamental iron-work in a conservatory picked out with bright blue or chocolate ; the fact having evidently been forgotten that it is the contents and not the structure which should be made prominent. While, however, hideous taste exists, we may expect to see in conservatories the murder of plants and flowers perpetrated by means of bright-coloured glass, blue and chocolate paint, and other wild vagaries.

To paint a house periodically is a bare necessity. It is true economy to protect the materials from the exceptionally trying atmospheric influences which surround horticultural buildings. If they have three to five coats when erected, they should have one coat outside within at least a year; after this say two coats outside and in, every three years.

Whenever fresh panes are put in, the wood-work and putty, as left by the removal of the old glass, should not remain bare till the next periodical painting, but should be painted immediately after the new pane is inserted.

Hot-water pipes may be painted in the ordinary manner, and the smell, which lasts for some time, caused by the heated drying oil, will probably not be found so disagreeable in a green-house as in a dwelling-house. If the pipes require to have a gloss on them, the expensive varnish-paint called brunswick black may be used with advantage ; or vegetable black, mixed with good boiled oil and a very small quantity of driers, may be employed. In any case the smell would probably not last very long. If any smell requires to be entirely avoided and a dead colour is not an objection, the oil may be left out of the paint, and colour and turps employed ; or a distemper wash (colour and water) may be put on the pipes; or the pipes may be blackleaded. This method, however, is not always satisfactory, as if the surface became wet during syringing, the pipes would have to be re-blackleaded.

Plate 41.



TRAINING WIRES.

TRAINING RODS or wires for the interior of glass-houses may be divided into three classes: For roofs; for back or other walls; and unsupported by either roofs or walls. These may be fixed vertically (or parallel with sash-bars) horizontally (or at right angles to sash-bars) or both vertically and horizontally. Frequently iron rods are used which, by their sheer thickness, preserve their rigidity for any length, by being merely supported without being strained. For ordinary purposes these are costly, cumbersome, heavy, and quite out of all proportion to the weight they have to sustain. A galvanized iron wire, about No. 12 Birmingham wire gauge, properly strained and supported at intervals, is light, cheap, as strong as is ever required, and answers most purposes.

VERTICAL WIRES.

For vines, melons, cucumbers, &c., which require to be trained under the glass, the following will, on consideration, be found the simplest and most advantageous arrangement.

We will suppose that the house is a lean-to, and the principal rafters and corresponding mullions are 4 to 5 feet apart, while the intermediate sash-bars are 10 inches to 1 foot apart. Let one wire be parallel with and about 10 inches under each sash-bar and rafter. To do this, two longitudinal flat iron bars turned edgewise may be held at the necessary height along the back and front by holdfasts at intervals, bolted at back through the wall and at front into each mullion. To these two bars the wires, passing through guiding and sustaining eyes screwed into the sash-bars may be fixed at intervals, being strained at one end by an ordinary tightening "raidisseur" (see Fig. 70), by a right and left-handed screw working simultaneously in a socket attached to the wire, or by a long screw and a back-nut. This system is simple, enables the wood or iron framework to be easily painted, acts as tension-rods to the structure, and helps to resist lateral thrust on the back and front walls.

Fig. 70.

If the house be a span instead of a lean-to, the iron bars will require to be held fast to the mullions on each side and the wires strained between them, after being passed either through eyes screwed into the ridge plate or through holes in a third flat iron bar suspended under the ridge; care being taken that the iron bar or eyes are at a proper distance from the glass. By the bar system, it will be seen that a gardener can shift the wires along the bar, group them in various ways, remove them altogether, or replace them with great ease. If the wires in a span-house are not required to be adjustable, one of the longitudinal bars may be omitted and the wires on that side fixed direct to the wood-work.

Modifications of this system may, of course, be required for houses of different shapes and aspects, but the above remarks will be applicable in most cases. Sometimes three parallel vertical wires are strained to T shaped holdfasts screwed into each mullion, such holdfasts having a hole at each end and in the centre of the upper member, which is 18 inches across, thus enabling the wires to be 9 inches apart. As will doubtless be seen, this is neither so strong nor so reliable as the previous arrangement mentioned.

HORIZONTAL WIRES.

Wires at right angles to the sash-bar are sometimes used, but they prevent the framework of the roof from being painted with such ease, afford no resistance to lateral thrust, and are not usually found so advantageous as wires parallel with sash-bars. A network of wires, both at right angles to and parallel with sash-bars, is occasionally used, but the obvious difficulty such an arrangement presents in getting at the roof for repairs, &c., and its additional cost, coupled with the absence of any corresponding prominent advantages, does not warrant its recommendation. When it is necessary to provide a support for fruit or other trees against the back wall of a green-house, this can easily be done by straining horizontal wires placed about 10 or 12 inches apart, each wire fastened to a staple at one end, and to a "raidisseur" or other method of tightening, as detailed above, at the other, passing each wire through guiding eyes driven into the wall at intervals of about 10 feet. The length of wire which may be strained depends on the strength of the terminal holdfasts, but from 100 to 150 feet may usually be strained with ease. It is usually found that the back walls in lean-to peach-houses may be wired, and that there is not always a corresponding advantage in wiring the back walls of vineries. Peach trees are not generally so long in stem, nor do they afford so much obstruction to the sun's rays at the back of the house as vines.

RIGID SUPPORTS.

If espaliers or other trees require to be trained in a house unsupported by either roof or walls, this can be done by driving into the ground or supporting on brick piers at intervals, wrought-iron standards of the required height, having holes drilled in them about 10 inches apart, through which the wires can pass. Of course each length of such wiring requires two strong terminal standards, to one of which the wires are fixed, and to the other strained by "raidisseurs" or other means. This system is frequently carried out in lean-to peach-houses and other growing structures, in which it is not desirable to wire the whole of the roof, in consequence of the trees planted in the front border not attaining a great length of stem; and in consequence of supplementary trees being trained up the back wall.

There is one mode of arranging training wires, which has sometimes been carried out, but which is only mentioned here for the purpose of being condemned. It is to fix a vertical trellis at intervals, transversely to the length of the house, spaces being provided, by means of an archway in each trellis, for the path. Trees trained on such trellis work are turned edgewise to the glass, and, in fact, form a series of arboreal partitions along the house. Of course this plan may enable a larger area to be utilized than when a training trellis is arranged in the usual way (viz., in planes parallel with the roof and front), and, if the house be a lean-to facing south, ensures the back wall having a certain interval of freedom from much foliage shading. But it is obvious that when the trees are only a short distance apart (as they would have to be, or the advantage of economizing space would be lost) and their edges are turned towards the south, part of the time they would shade each other, and part of the time the sun would shine on their edges only. In either case they could not receive the full benefit of the sun's rays. Moreover, most of the branches would be far from the glass, aud the back wall could only be unshaded for a short time at mid-day. If the house, instead of a lean-to, were a span, with the ridge in the direction of either north and south, or east and west, similar disadvantages would result.

TRELLIS.

Diagonal painted wood trellis may sometimes be used with advantage against the back walls of green-houses for sustaining creepers; against dwarf walls, to hide naked brick-work; and in front of staging to mask hot-water pipes; but it must be used very judicially, and so fixed that it can easily be taken down in large portable panels or pieces for repair, cleaning, painting, &c. If wood trellis does not receive careful and periodical attention, it may harbour insects to the prejudice of the valuable contents of glass-houses. Trellis used in ornamental houses may frequently be rendered effective by being constructed in a neat geometric pattern. By such a plan it can more readily be made portable.

OPENING GEAR.

BY opening gear is understood any contrivance by which ventilators, either in the roof, vertical front lights, or any other part of a house, are opened by one or more operations. In this, as in all other machinery for attaining a given result, the simplest in action will be found the best.

SET-OPENS.

In opening vertical swinging lights separately, whether hung on the centres, at the top, or at the side, the usual set-opens are iron arms or quadrants, having holes drilled or notches cut at intervals, to catch on a fixed vertical pin. The length of these arms will depend upon the position they occupy, and whether the staging in front of the lights is broad or narrow. Wherever staging is not used, and a pathway is very near the vertical lights, the set-opens are usually made with a swivel joint, so that when the ventilators are closed, the arms may be swung close to the mullions or sills without causing any obstruction. When staging is placed in front of the lights, the set-opens should always be kept at right angles to the ventilators, or space on the staging for pots will be unnecessarily occupied in swinging the set-opens round.

In opening roof ventilators separately, a quadrant terminating with an eye may be fixed to each light. A cord attached to the eye and passing over a small pulley fixed to the purlin or principal, will be sufficient to open the light. A counter-balance weight may be attached to the end of the cord if necessary. (See Fig. 71.) Or the cord may be passed over a pulley attached to the back wall and fastened at any convenient spot, or terminate in a counter-balance weight.

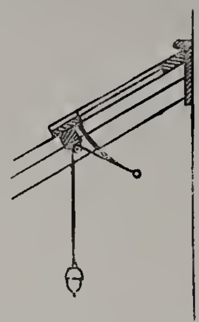


FIG. 71.—Opening gear for separate roof lights.

Sliding lights, except for small work not requiring opening gear, are now practically abandoned in favour of hinged ventilators ; therefore, any arrangement for opening such sliding lights need not be discussed here.

SIMULTANEOUS GEAR.

In opening a number of vertical lights simultaneously, the most usual and best plan is to run through small bearings fixed to each mullion, a rod, on which are fixed, at proper intervals, say two to each light, the ends of

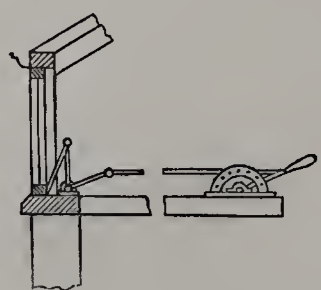


FIG. 72.—Lever simultaneous opening gear.

elbow joints, the other ends being attached to the bottom rails of the lights. When the rod is caused to partially revolve, the whole of the elbow joints are straightened, and in the action of straightening, the sashes are opened. To actuate the rod, it is only necessary to screw on to it, at any convenient point, a lever, moving along an iron arc pierced with holes for adjusting the opening of the sashes. Or if stages, beds, or borders, are in front of the lights, the lever may, by means of a rod, be fixed at any convenient distant point. (See Fig. 72.)

These elbow joints are better than rack set-opens, worked by toothed pinions fixed on the rod. When the lights are shut, such rack set-opens project into the house and are very liable to interfere with plants and flowers; whereas elbow joints, when either shut or open, never come in contact with plants or pots. Care must be taken that "play" is not allowed to any of the connecting parts of the gear, or the wind may cause the lights to rattle and great inconvenience may result. Instead of the lever and quadrant, described above, especially when speed is required to be sacrificed to power, a worm and pinion movement is occasionally employed to actuate the revolving rod; but this in practice, if it can be avoided, is scarcely to be preferred to the lever gear, as the wearing of the pinion against the worm is almost certain, after a time, to cause a little objectionable "play."

The foregoing remarks, although referring only to vertical lights, apply equally to roof or any other similar hinged ventilators. It must not be forgotten that the strength of simultaneous opening gear will depend upon the weight of the lights to open. The heavier they are and the less they are in equilibrium, the greater will be the power required to manipulate them. Care must be taken that the set-opens are firmly secured along the rod, either by key-ways or set-screws sunk into the rod, or some of the set-opens may slightly alter their position. In this case all the ventilators, or all parts of them, will not close simultaneously; the frames will be strained, will warp, and great inconvenience will result.

Various contrivances are employed by different firms to produce the simultaneous opening of ventilators, but the above-mentioned systems are those which are usually adopted as the most advantageous. Sometimes motion is conveyed from the ventilators to the hand of the operator by chain gear, but any one who has had much experience of chain gear for lawn mowers, traction engines, or for transmitting power of any description, will hesitate before introducing it into horticultural buildings.

APPLICATION OF SIMULTANEOUS GEAR.

Simultaneous gear should be very judiciously employed. Under ordinary circumstances, for small or medium-sized houses, where the vertical lights are easily reached, simultaneous gear is worse than useless. For it is frequently advantageous to open certain lights and leave others in close proximity closed, either in consequence of the direction of the wind or because plants in certain portions of the house require protection from direct currents of external air. With simultaneous gear, a certain number of lights must be opened equally. In cases where vertical lights are at some little distance from the path, and to reach the lights would necessitate treading on vine borders; or 4 or 5 feet of bed in a forcing-house, or stage in a plant-house, intervenes between the path and the lights; either a long and clumsy set-open to each light must be used, or what is preferable, simultaneous gear.

Sometimes several consecutive ventilating lights are framed together. In this case simultaneous gear must be fitted in the same way as for separate lights, as the frame will be certain to warp and twist, if the opening bearings are too few. With front vertical ventilation, framing a series of lights together is objectionable, as it precludes the possibility of opening the lights separately at any future time. This objection does not apply equally to roof ventilators, as the necessity will seldom occur for these to be opened separately. It is not usually advisable, except in the case of a long unpartitioned building, devoted to one object, to open simultaneously more than about 20 to 25 feet run of either top or bottom ventilators.

STAGING.

WHEN plants require to be raised above the ground, the staging to effect this may be composed of different materials to suit varying circumstances.

WOOD STAGES.

If a stage be wanted which shall, while forming a support for pots, drain the water and prevent an accumulation of moisture, there can be nothing better than ordinary deal laths, say 3″ by 1″, having a space of $\frac{3}{4}$″ left between them, and carried on bearers at short intervals; these bearers, supported at the proper height by legs or brick-work. Such an arrangement is the "lattice wood stage."

In planning stages, study economy of space and convenience. Do not have two paths if one will suffice. Do not have stages made in inaccessible widths. Look well to the distance between the stages and the glass. Have regard to the description of plants intended to be grown and their height. The good or bad planning of a stage will depend upon the attention which all these points receive. Although each case must rest upon its own merits, the following hints may be useful :—

STAGES FOR SPAN-HOUSES.

In span plant-houses up to 12′ 0″ or 13′ 0″ feet wide, one central path and a flat stage on each side is the most economical arrangement. (See Fig. 73.)

The most convenient height for a flat stage is 2′ 6″ above the floor line, or about the same height as the brick-work supporting the vertical lights of usual growing-houses. Supposing the paths be uniformly 2′ 9″

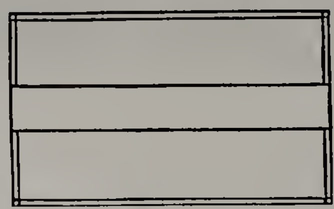


FIG. 73.—Plan of stages for narrow span-houses.
Scale, $\frac{1}{16}$ inch = 1 foot.

wide and each of the side 9″ walls be occupied by $4\frac{1}{2}$″ of wood-work, Table XII. will show the width of stages.

TABLE XII.—DIMENSIONS OF STAGES FOR SMALL SPAN-HOUSES.

Width of House.	Width of Stage at each Side.
10 feet.	3 feet 3 inches.
11 ,,	3 ,, 9 ,,
12 ,,	4 ,, 3 ,,
13 ,,	4 ,, 9 ,,

4′ 9″ for all ordinary plants is certainly the extreme limit of width which a flat stage should be allowed to reach. For not only is it troublesome for a gardener to attend to pots and plants over any longer "reach," but where vertical sashes have to be opened separately without the aid of simultaneous gear, the "set-opens" on each sash must be abnormally long and form an obstruction, or the gardener's arms will ache and his temper be ruffled.

A span plant-house beyond 12′ 0″ or 13′ 0″ feet wide should certainly have two paths. (See Fig. 74.)

This gives two flat side stages and a central stage, which may be either flat or tiered, as may be most convenient and necessary. Supposing the paths are each 2′ 9″ wide and 4½″ is taken up on each side wall by the wood-work, the dimensions given in Table XIII. may be allotted to the

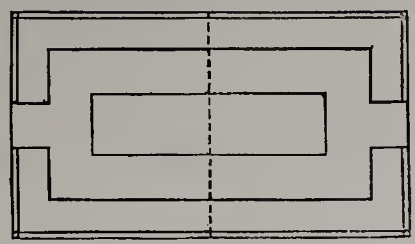


FIG. 74.—Plan of stages for wide span-houses.
Scale, $\frac{1}{16}$ inch = 1 foot.

central and side stages.

TABLE XIII.—DIMENSIONS OF STAGES FOR LARGE SPAN-HOUSES.

Width of House.	Width of Central Stage.		Width of each Side Stage.	
ft.	ft.	in.	ft.	in.
14	3	9	2	0
15	4	9	2	0
16	4	9	2	6
17	5	9	2	6
18	5	9	3	0
19	6	9	3	0
20	7	3	3	3

The side stages should be of a sufficient width to allow of good head room in the path. If a house be 5′ 0″ high to gutter line, and the pitch of roof be not less than 6″ in the foot, a 2′ 0″ side stage will give about 6′ 6″ clear head room in the centre of adjoining path. The proportions for tiered staging will be discussed later. Where one span plant-house immediately follows another, or where the interior arrangement will allow, the two paths need not converge into one, as shown at each end of Fig. 74, but may be made continuous. Staging space is thus economized. This arrangement will be rendered clearer if Fig. 74 be taken to represent two houses instead of one, formed by a partition and doors being placed across it at the dotted line.

STAGES FOR LEAN-TO HOUSES.

In lean-to plant-houses a very convenient mode of planning the stages is shown by Fig. 75.

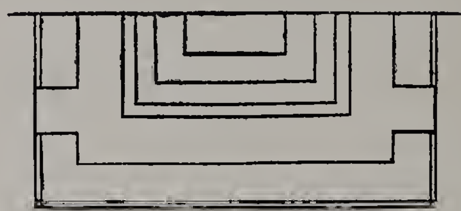


FIG. 75.—Plan of stages for lean-to house.
Scale, $\frac{1}{16}$ inch = 1 foot.

In this there is a flat stage in front, continued at the ends, with another flat or a tiered stage at back. In any case it is not advisable to have the front stage too wide, or the back stage, even though it be tiered, may be too far from the glass.

When a lean-to house is too short to admit, conveniently, of the front stage being returned at the ends, this front stage as well as the back stage may be continued straight through, as shown by Fig. 76.

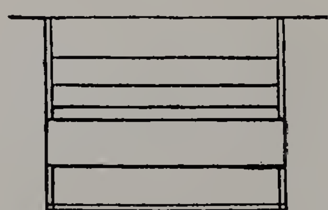


FIG. 76.—Plan of stages for short lean-to house.
Scale, $\frac{1}{16}$ inch = 1 foot.

Taking the path at 2′ 9″ wide, and the space occupied by wood-work on front wall as $4\frac{1}{2}''$, Table XIV. will show convenient dimensions for front and back stages with different widths of lean-to houses.

TABLE XIV.—DIMENSIONS OF STAGES FOR LEAN-TO HOUSES.

Width of House.	Width of Front Stage.		Width of Back Stage.	
ft.	ft.	in.	ft.	in.
10	1	$10\frac{1}{2}$	5	0
12	2	$4\frac{1}{2}$	6	6
14	2	$10\frac{1}{2}$	8	0
16	2	$10\frac{1}{2}$	10	0
18	2	$10\frac{1}{2}$	12	0

Of course in wide lean-to plant-houses, it may be found necessary to have a walk along the back, as well as near the front, in order that the back part of the back stage may be more accessible. In this case the path had better be directly against the back wall, but the staging space thus occupied need not be entirely lost, as a small shelf overhanging the path, above the head line and the top of back stage, will be found very convenient. The same general remarks will apply to staging for three-quarter span-houses.

TIERED STAGES.

It has been a past fashion to make a ladder, step, or tiered stage, especially in lean-to houses, rise from the ground to the ridge by a large number of small steps of equal width. While this may still be considered suitable by some gardeners, it will generally be found more advantageous to have a smaller number of steps, increasing in width as they rise higher. This will be found to economize space and provide better accommodation for pots and plants of varying size. The first step of a back tiered stage may be on the same level as the front flat stage, say 2′ 6″ above the floor line. Each succeeding step may rise 6″ to 9″ higher. No arbitrary rule, however, can be laid down on this point, as much will depend upon the height, &c., of the plants to be staged. In a usual way, the inclination of tiered staging need not be so steep as the pitch of the roof, so that the shorter plants in front and the taller behind, may cause the line of foliage to preserve, roughly, the same inclination as the roof.

With the varying conditions of the plants to grow, pitch of roof, width of house, &c., the dimensions of tiered stages must necessarily vary. But for general purposes, Table XV. will show how tiered-back stages for lean-to houses may be composed; presuming, of course, that it is desirable to carry such stages right up to the back wall without having a path at the back, as described at the end of the previous section. If it be desired to return the ends of the back stage, and the house be not long enough for this purpose, the number of steps had better be reduced.

Table XV.—Dimensions of tiered stages for lean-to houses.

Width of Lean-to House.	Width of Back Stage.		Steps composing Stage.	
			No.	Width in inches.
ft.	ft.	in.		
10	5	0	4	9 12 15 24
12	6	6	4	9 15 21 33
14	8	0	5	12 15 18 21 30
16	10	0	6	12 15 18 21 24 30
18	12	0	6	15 18 21 24 30 36

Lean-to growing plant-houses seldom require to be so wide as 16′ 0″ or 18′ 0″.

Tiered stages for span-houses are rather easier of treatment. The steps descending on each side towards the path make such a tiered stage more accessible. The same remarks with regard to varying conditions for tiered stages in lean-to houses will hold good with tiered stages for span-houses;

but for general purposes the dimensions in Table XVI. will be found suitable.

TABLE XVI.—DIMENSIONS OF TIERED STAGES FOR SPAN-HOUSES.

Width of Span-House.	Width of Centre Stage.	Width in inches of each Step which is carried round.	Width in inches of Top Step.
ft.	ft. in.		
14	3 9	12	21
15	4 9	9 9	21
16	4 9	9 9	21
17	5 9	9 12	27
18	5 9	9 12	27
19	6 9	12 12	33
20	7 3	9 9 12	27

NOTE.—As each step carried round really forms two steps in the whole stage, twice the sum of the dimensions in the third column, added to the dimensions in the fourth column, will equal the dimensions given in the second column.

In all the above staging, the line of glass is followed to a certain extent. In some instances, however, this has to be abandoned, notably in the case of some conservatories or flower rooms. Where it is advisable to have a bank of flowers, and where the effect cannot be produced in a purely natural way, staging may be introduced, of which the highest tier rests on the top of the low 2′ 0″ wall carrying the glass-work, and each succeeding tier descends nearer the ground. In this case the direction of the inclination of the staging will be opposite to that of the roof. Fig. 77 shows a small octagon-ended conservatory having the above treatment of staging.

If the inside width of this conservatory be, say 12′ 0″, each step may very well be 1′ 9″ in width, leaving a good paved space in the centre 5′ 0″ wide. It is advisable to have the steps of this description of stage, if anything, wider and vertically closer together than the steps of the staging of growing-houses, in order that the sharp lines formed by the edges, may not be so prominent. If wood-legs are used for such staging, those in front

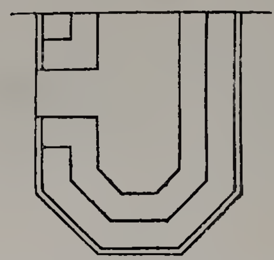


FIG. 77.—Plan of conservatory stages.
Scale, $\frac{1}{16}$ inch = 1 foot.

may be turned. Lattice wood-work is sometimes fixed in front of staging to mask hot-water pipes or vacant space.

When tiered staging consists of many narrow steps, they are frequently supported, as shown in section by Fig. 78. With wider steps a much better mode is shown by Fig. 79.

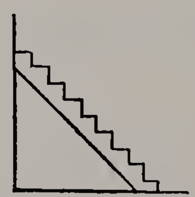


FIG. 78.—Section of support or tiered stage with narrow steps.

FIG. 79.—Section of support for tiered stage with wider steps.

SOLID STAGES.

In many instances, it is advisable to maintain the pots moist, when shelves of slate, stone, or concrete, having marginal strips, are frequently used. A very cheap and easily constructed form of this class of staging is to take an ordinary flat lattice lath stage, as already described, plant a fillet round the edge, and line the interior with sheet zinc, say No. 20 B.W.G. We thus have really a very shallow water-tight box. Care must be taken to make holes at the corners or at convenient intervals, and also to slope the staging very slightly towards these holes, so that superfluous moisture may be carried away. This shallow box may then be filled with sand, fine gravel, moss, or other suitable material, when the pots will rest in a damp but well-drained bed, or such a stage may be used dry, when the pots may be placed on a thin layer of washed gravel or small pebbles, covering the stage; such gravel or pebbles forming the vehicle for the drainage of the pots. This stage always has a very neat appearance, it is cheap, and the wood-work composing it is not so liable to rot as when unprotected from the drainage of the pots.

A subsidiary, but very important stage is the "strawberry shelf." This (not always restricted to strawberries) requires to be near the glass; either close to the glass in front; near the apex of span-houses; or on the back wall near the ridge of lean-to or three-quarter span-houses. It is very advisable that the pots placed on such shelves should be protected from the excessive rays of the sun, and an easy mode of doing this is to fasten vertical boards, nearly as high as the pots, on one or both sides of the strawberry shelf; to line the interior with zinc, or not, as may be thought advisable; to provide draining holes for the box thus formed; and to further protect the pots by damp moss if necessary.

When stages are of stone, slate, or zinc lined, and the heating pipes are required to be on one side of the path, it is often advisable to provide for such pipes being out of the way, by slightly retiring the supports to the front of the stage on one side. On the other hand, if the heating pipes be placed next to the outer wall, and the front of the stage be supported by a wall, so as to form under the stage a more or less confined chamber, it is advisable to provide ventilators in the inner as well as the outer walls, so that the heat may have other means of arriving at the interior of the house than by way of the stage. Under the section "Mushroom-House," p. 80, will be found a description of the shelves required for such a house.

ORNAMENTAL IRON STAGES.

These are seldom required in growing-houses, their use being chiefly confined to conservatories. As mentioned in the article "Show-houses,"

p. 63, plants and flowers when collected for show purposes, should be grouped in as natural a manner as possible, and staging abandoned for beds and borders. When staging becomes, from any reason, an absolute necessity in a conservatory, there is no objection to employ ornamental pierced iron castings, but they must be kept well painted, must not be high, and must be hidden as much as possible by the foliage, so that they are not obtrusive. Wooden lattice staging is much cheaper than iron, with care will last a long time, and, in the author's opinion, answers every purpose. Space under a wood, slate, stone, or concrete stage, may frequently be utilized for plants requiring heat without light, but plants placed under an iron stage may never be considered safe from damage by rust-drip.

VENTILATION.

GENERAL PRINCIPLES.

ALTHOUGH a plant is nourished mainly through its roots, its leaves act as lungs, and air is necessary to enable it to carry on its functions. The respiratory organs of animals as wel as the stomata or respiratory organs of leaves demand a constantly renewed supply of air. When plants, therefore, by reason of the exigencies of cultivation, are grown in a confined space, means become necessary for a constant renewal of the air in a proper manner. The subject of ventilation is of such paramount importance in connection with the artificial growth of plants and flowers, that special attention should be directed to some of the elementary principles involved, as well as to their application; more particularly as plants, which are peculiarly liable to suffer from variations of temperature, cold currents of air, &c., unlike animals, have no power to protect themselves from these adverse influences.

The principle which rules ventilation or the motion of currents of air, is, like all great laws, extremely simple, though capable of complex application. It is that "air expands when heated, and contracts when cooled." So that hot air rises, and cold air sinks. Thus, taking the volume of air at 32°

Fahrenheit as 1000, the volumes at various temperatures will be as follows :—

TABLE XVII.—RELATIVE VOLUMES OF AIR AT DIFFERENT TEMPERATURES.

Temperature in Degrees Fahrenheit.		Volume.
Below Zero	50°	832·7
,,	20°	893·9
,,	10°	914·3
Zero	0°	934·7
Above Zero	32°	1000·0
,,	50°	1036·7
,,	60°	1057·1
,,	70°	1077·6
,,	80°	1098·0
,,	90°	1118·4
,,	100°	1138·8
,,	110°	1159·2
,,	120°	1179·6
,,	130°	1200·0

Now, as air is increased in volume by raising its temperature, so air occupying a given space, will weigh less than colder air occupying the same space. In other words, the specific gravity of the colder air will be greater than that of the hotter air. Therefore when a column of hot air is in proximity to a column of cold air, the latter pushes the former upwards. So that when we say hot air rises, we know it does this, not because of any inherent power, but simply because it is over-balanced by air occupying an equal space, not so hot, and consequently heavier. Hot air would absolutely sink if the air in contact with it were hotter. Thus far we have been speaking of vertical equilibrium only. Air, on being heated, is pushed upwards by colder air, but the latter, in taking the place of the former, may not only require to descend, but may pursue a diagonal, horizontal, or circular course. Obstructions to its direct course may occur. Its motion may "induce" other currents. Or a combination of conditions may ensue which may cause such a mobile material as the air to move in a manner apparently aimless, although strictly following natural laws.

EXAMPLES.

Before discussing horticultural ventilation, we will give one or two simple examples of variations in temperature affecting the motion of currents of air. We will imagine Fig. 80 to represent the vertical section of a room A B C D, in which there are neither inlets nor outlets for air, and in which the interior air and the surrounding walls are heated to the same

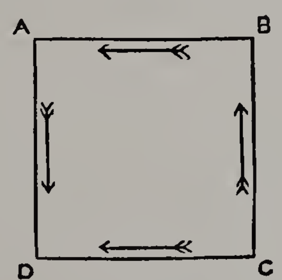


FIG. 80.—Vertical section of a room showing direction of currents of air.

temperature. No current of air exists in the room. But if the wall A D be cooled, the air next this wall will have some of its heat abstracted, it will be rendered heavier than the remaining air, and it will at once commence to descend. In descending, other currents will be induced, such as shown by the arrows.

Again, if the side B C be heated above the temperature of the air in the room, that portion of the air in proximity to the wall B C will rise, and currents of air will be put in motion, in much the same manner and direction as if the wall A D were cooled below the temperature of the room.

Take another example of the room A B C D, Fig. 81, with the interna

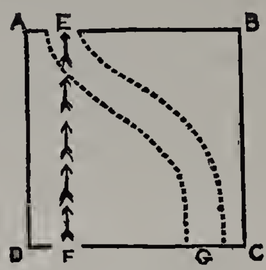


FIG. 81.—Vertical section showing direction of currents of air.

air and walls heated to the same temperature, such temperature being higher than the external air. If openings be made in ceiling and floor at E and F, the column of air E F, being warmer than the external air, will at once rise. But the portion of the room to right of this column of air will be liable to remain without sufficient ventilation.

If, instead of openings at E and F, openings be made at E and G (see dotted lines, Fig. 81), there will be air in motion from one aperture to the other, but the air in that part of the room nearest D will have a tendency to remain, for practical purposes, unchanged.

As may be gathered by the Table on p. 132, the greater the difference between the temperatures of the warm rising and cold falling air, the greater will be the difference between the respective specific gravities, and consequently the greater will be the velocity of the currents produced by such variation in temperature. Hitherto we have been dealing with a single column of air in motion. It may be stated in general terms that if, instead of one column of large sectional area, we have several small ones, the rate of velocity is increased. If, again, we have a very great number of minute ones, the rate of velocity is brought even lower than before. These three modes of dealing with a column of air may be illustrated by air passing through a window opened wide; through a number of 2-inch holes; and through a piece of perforated zinc or wire gauze. In the first instance a breeze is felt; in the second a draught; and in the third probably less breeze than in the first. In ventilating our horticultural buildings, therefore, it is necessary, by the position and size of inlets and outlets, and by the position and intensity of the heat-radiating surface, to regulate the columns of rising air; their velocity; their ability to change the internal atmosphere; and to produce the admission of fresh air and exit of vitiated air, when and how we consider necessary.

If all the air in a neighbourhood were at perfect rest except that portion with which we wished to produce ventilation, the subject would be very easy of treatment. But when, especially as with horticultural buildings, we have constantly varying temperatures of internal and external air; steady winds; eddying currents; local and other obstructions; the case becomes more complicated.

In factories, large establishments, mansions, and other similar buildings, mechanical ventilation can be provided with comparative ease and economy. Fans for instance, may be employed in two different ways, either by compression or exhaustion. Air may be pumped in or pumped out, and the proper balance may be maintained between the vitiated and fresh, the warm and cold air. Or a chimney shaft may be employed as an exhauster. A fire at the bottom of such a shaft will keep a column of air always in motion, and this current may be employed to renew air in any apartment or building which may be necessary. An application of this principle to ventilate a fruit-room may be easily carried out by burning a gas jet just within the lower part of a small shaft carried through the roof or into the open air from such an apartment. Rotating screw ventilators worked by the wind may also be used to exhaust air. But in horticultural buildings constructed of glass, it is seldom possible to employ any other means of mechanical ventilation than the hot-water apparatus. This, however, with care, and by treating each case on its own merits, is quite sufficient to produce ample and efficient ventilation.

APPLICATION TO HORTICULTURAL BUILDINGS.

Keeping before us the great principle of currents of air being caused by varying specific gravities of different columns of air, with the contingent circumstances arising therefrom, let us take the example of a hot-water heated green-house (shape immaterial), and in a few words sum up the operations involved in ventilating it, or keeping it constantly supplied with fresh air. First of all we will assume that the heating apparatus has not been set to work, and that the temperature inside the house is the same as that outside. We will also assume that the heating apparatus is placed near the ground, and that there are ventilators near the ground, and others near the apex of roof. No currents of air exist, and no ventilation consequently takes place. Such an imaginary building may be illustrated by Figs. 82 or 83.

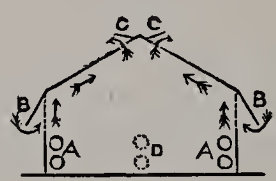


FIG. 82.—Vertical section of a span-house showing direction of currents of air.

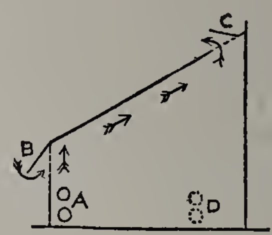


FIG. 83.—Vertical section of a lean-to house showing direction of currents of air.

The heating apparatus A is set to work. The column of air over it is heated, expands, and begins to rise. The outlets at C allow this column of light air to rise through the roof, and the inlets at B allow heavier air to enter and replace it. This heavier air coming in at B is at once heated by the pipes A, expands, rises, and the operation is repeated again and again. But this renewal of air may take place so rapidly, that the temperature inside the house may not be allowed to rise as high as the exigencies of the plants may demand. Two courses are then open. Either to increase the power of the heating apparatus, or what is better, decrease, first the apertures of outlet at C, then those of inlet at B. Upon the proper combination of these courses depends, in a great many instances, the effective ventilation of horticultural buildings.

Figs. 82 and 83 may be taken to represent small houses. If the houses were anything more than a moderate size, pipes would be required nearer the centre of floor in Fig. 82, and nearer back wall of Fig. 83, say at D, in order that an equable heating of the air might take place in the respective houses, and none of the air be liable to remain in a stagnant, unrenewed condition. Other inlets than those at B might also become necessary. For instance, fresh air might be required to be brought by horizontal shafts to the point D.

As a rule, for heated structures, the outlets may have a much smaller collective area than the inlets; in fact, frequently a mere narrow strip of ventilating area along the ridge, is most effective for the outlet. A corresponding but wider strip of ventilating area along the lower vertical lights being used as the inlet. In this way the air is not so liable to be stagnant in any part of the house. Further, the greater the difference in temperature between the internal and external air, and the greater the ventilating velocity, with the greater ease will the ascending column of air overcome the external obstacles of contrary currents, when escaping from the outlets C. Should, however, the outlets C be larger than the inlets B, and external winds prevail, the current may be reversed and the cold air rush in at C and out at B; an effect which is to be guarded against, for, if possible, cold air should obviously not be allowed to enter at the top of the house and pass over and through the plants before it reaches the heating apparatus. On the other hand, there are instances, such as in unheated orchard-houses, in which ventilators are required to perform another duty, namely, to allow plenty of sun-warmed external air to enter the house during the day, and then, when closed, to retain the warmed air during the night, when the external temperature sinks.

FORMS OF VENTILATORS.

Ventilators may be of various kinds.

(*a*) Framed sliding lights. (*b*) Framed lights or shutters, hinged at the top, and describing part of a circle when opened. (*c*) Framed lights or shutters, pivotted on the centre and opening inwards at the top and outwards at the bottom. (*d*) Framed lights or shutters, hung on hinges at the side and opening in a similar way to casements. (*e*) Window sashes. (*f*) Sliding shutters or doors. (*g*) "Hit-and-miss" gratings or panes. (*h*) Lights or shutters, by parallel or other motions, receding from, and in the same plane as, the surrounding fixed glass-work. (*i*) Suction ventilators. (*k*) Throttle ventilators. (*l*) Permanent openings.

(*a*) Framed sliding lights. Until recently these were almost universally employed as roof ventilators, but they are now generally abandoned for the following reasons :—They are clumsy and their adjustment develops a large amount of friction. The rafters between which they slide require to be abnormally deep and heavy, thus causing unnecessary obstruction to the solar rays, and additional harbour for insects and moisture. When drawn down, the sash-bars of sliding lights super-imposed and at a little distance above the sash-bars of fixed framework cause further unnecessary obstruction to the solar rays. When opened, they admit the rain directly into the house, and if the wind be blowing from the back, the rain and cold air can be blown towards the interior front of the house. Certainly it may not always be considered objectionable for rain to drift in, but in frequent cases the rain is of too low a temperature to be allowed to come in contact with hot-house plants. Another objection to such sliding lights is, that although they can separately be counter-balanced by weights, the amount of friction to overcome in opening or closing several at one time renders it difficult to manipulate them simultaneously. Sliding lights, however, are still employed with great advantage in cucumber frames, &c. When they are used for this purpose it is better that the lights should slide up as well as down, in order that ventilation may be given to the highest as well as the lowest part of the frame at will, and also in the case of heated frames, that cold air may be admitted first to that part of the frame near the hot pipes. Sliding lights are also advantageous when, as in the case of some wall-tree covers, the lights require to be entirely removed during a part of the year.

(*b*) Framed lights hinged at the top and describing part of a circle when opened. These are as easily applicable for roof ventilation as for vertical front lights of growing-houses. This method reduces friction in opening and closing to a minimum. They can be easily worked simultaneously when required. Rain is not so liable to drift in. Their presence does not necessitate any heavier scantling than their absence. They afford the minimum of obstruction to the solar rays. Less complication is involved in their construction than almost any other system of ventilators, and they may fairly be considered to merit the distinction of being the most suitable ventilators for horticultural growing buildings. The same system is also applicable where wooden ventilators are necessary, such as box ventilators to let into brick-work; lower ventilators of forcing pits; or wall-tree covers, in which there may not be sufficient height for vertical glass-framed ventilators.

(*c*) Pivotted ventilators. These are similar to the last described ventilators (*b*) but instead of being hinged at the top, are pivotted at the centre and open inwards at the top and outwards at the bottom. In some respects these are more advantageous than the hinged ventilators (*b*) as the former are in equilibrium, and consequently require less power to open them. But they should seldom be used, except for large iron or other conservatories, where the area of each ventilator may be large; where minimum projection of ventilators when opened is to be aimed at; and where power in opening or closing is a point of considerable importance. For all ordinary growing-houses, pivotted ventilators have several objections. Half of each ventilator must open inwards, and must consequently be liable to interfere with vines, plants, flowers, &c., which may be in proximity to them. Used as roof ventilators they would have a tendency to slope the rain inwards instead of outwards. The construction is more complicated than that of the hinged ventilators, and the mitred fillets against which each half on opposite sides butts, are more liable to get out of order. On the other hand, it must be conceded that pivotted ventilators are, perhaps, considered by some people to look a little neater and more workmanlike, than simple hinged ventilators. There is no need on any grounds whatever for box ventilators, small wooden shutters, &c., to be pivotted.

(*d*) Casement ventilators, or lights hung on hinges at the side. For growing-houses, it is seldom advisable to construct the ventilators in this manner; first, because each sash, when opened, admits the air from top to bottom, and consequently there is no possibility of warming the whole of the entering air; and, secondly, because simultaneous opening is not so easily effected. Casement ventilation, however, is a very convenient form for many conservatories and show-houses, inasmuch as it is a form which easily adapts itself to architectural design; the air is not so necessary to be heated as it enters as in growing-houses; it may be an advantage to admit air along the whole of the vertical height; and if the casements are made to open alternately in opposite directions, as shown in Fig. 84, ventilation may be obtained without any adverse influence of winds.

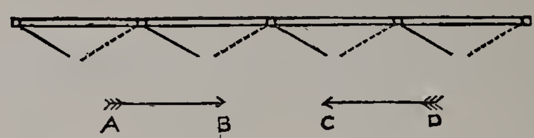


Fig. 84.—Plan of casement ventilators.

If the wind be blowing in the direction A B, the casements shown by solid lines may be opened and the casements shown by dotted lines, closed. If the wind blow from D to C, the dotted line ventilators may be opened and the solid line ventilators closed. This can easily be done, although there may be a closing fillet on one of every two consecutive doors.

(*e*) Window sashes. This mode of ventilation is of no practical value for growing-houses. The heavy cases for weights form an obstruction to light. When opened, the over-lapping sash-bars and frame are objectionable, as shown in sliding lights (*a*). They do not admit of simultaneous opening. They are more costly and more complicated than either ventilators, "*b*," "*c*," or "*d*." They are, of course, useful in such buildings as potting-sheds, seed and fruit-rooms, and other brick-built structures, only requiring an ordinary amount of light and ventilation.

(*f*) Sliding shutters or doors. There may be occasions when sliding shutters are useful, as for instance, behind windows in mushroom and similar houses, which, as a rule, require to be kept dark; but except being used sometimes as ventilators in brick walls and under special circumstances, sliding shutters for ventilation proper are not required for horticultural work.

(*g*) "Hit-and-miss" gratings. These are usually made in ornamental iron-work or in panes of glass. The latter would not, under any circumstances, give sufficient ventilation for horticultural purposes, the former may be sometimes useful for fixing in the brick walls of houses having no vertical lights; for letting cold air into, or hot air out of, the spaces below the beds of forcing-houses; or for maintaining an equilibrium between the bottom heat and atmospheric heat of cucumber or melon houses, &c.

(*h*) Lights or shutters, by parallel or other motion, receding from, and in the same plane as the surrounding fixed glass-work. This system, which is sometimes found useful in securing a small amount of ventilation along the whole of the ridge of an orchard or green-house applied transversely, in the same direction as the rafters, is generally considered objectionable by causing the cold air to come in contact with the foliage before the temperature is raised. In addition, this system possesses the disadvantage that owing to the joints not being so liable to close tightly in consequence of torsional strains, houses in which such ventilators are used can seldom be fumigated. Outside blinds cannot so readily be fitted to houses constructed in this manner.

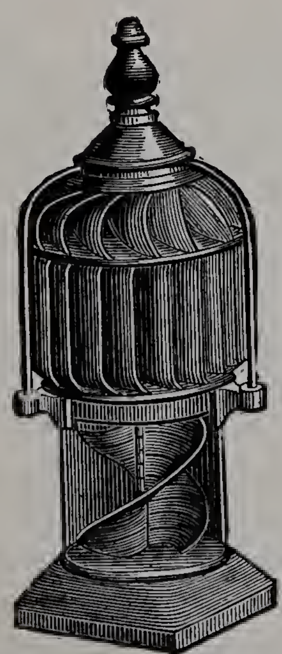


FIG. 85.—Howorth's patent Archimedian screw ventilator.

(*i*) Suction ventilators. These may be described as a very quick pitch screw revolving in a hollow cylinder, drawing the air as it revolves, and actuated by wind-vanes. (See Fig 85.)

They are of great use in drawing the vitiated air from public buildings, dwelling-houses, &c., but are seldom if ever applied for horticultural ventilation.

(*k*) Throttle ventilators are chiefly used in connection with Tobin and other air shafts. Although seldom employed for hot-houses, they may sometimes be usefully introduced into flower-rooms or conservatories, where the entering air requires to be sent in any direction, or where it is necessary that an absolute stream of cold air shall impinge upon hot pipes before being allowed to mix with the air in a structure. These, like the pivotted ventilators (*c*), are said to be in equilibrium, as, independently of the amount they are opened, or the rate at which the air passes them, they never have any inclination to open or shut, by reason of the pressure on one side of the pivot always counter-balancing that on the other. (See Fig. 86.)

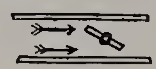


FIG. 86.—Longitudinal section of "Throttle" ventilator.

(*l*) Permanent openings. These in regard to growing-houses generally, may, of course, be considered anomalies. We merely mention this system of ventilation, as, although fresh air is necessary at all times and under all conditions, it is no less necessary that the admission of fresh air should be under control. Still, instances are not wanting in which a small area of open unglazed iron-work is introduced into corriders, large winter gardens, &c., for the purpose of maintaining permanent ventilation. The numerous crevices round even the best-fitting doors and sashes and other interstices may be looked upon as unavoidable permanent ventilators.

Taking the general exigencies of horticultural buildings, it must be borne in mind that all ventilators used should fit fairly closely, otherwise there may be difficulty in fumigating or smoking a house when required. If possible, air admitted to a hot-house should have its temperature raised to the required height as soon after its entry as possible.

Generally speaking, bottom ventilation (inlet) should be as low as possible; top ventilation (outlet) as high as possible. Also, generally speaking, both bottom and top ventilation should exist along the whole length of a structure. When possible, top ventilation should be placed in the position least liable to be affected by strong winds. Joints of all ventilators should be so constructed that when either opened or closed, the rain should not be liable to drift through and drip into the house.

SHADING.

MEANS for moderating the intense solar rays frequently require to be employed. These means may be of various kinds, viz.: by shading external and internal; permanent and temporary; effected by blinds; whitewash; paint; and semi-transparent or corrugated glass.

PERMANENT SHADING.

This cannot, as a rule, be considered so advantageous as temporary shading; for although the former may be very suitable for the height of summer, there are times when the whole of the available sun's rays require to be utilized. Of course there is an exception to this rule if ferns or plants are cultivated, which, in their natural state, flourish in nooks and dells and under dense foliage. In this case permanent shading is not only advisable but essential. The best kind of permanent shading is the obscured glass known as "Hartley's Rolled Plate," varying from $\frac{1}{8}''$ to $\frac{1}{4}''$ thick. The obscurity is due to corrugations on one surface of the glass only. Some kinds of rough plate, at a little distance, look mottled and irregular; but if the general surface be fairly regular, the glass will have a very neat and sightly appearance. Permanent shading by coloured glass has also been advocated in many quarters, with the object that the solar actinic rays and a sufficient quantity of the heat and light rays may pass through for the purposes of cultivation; but that the excessive heat rays may be kept back. This idea has not yet passed from the experimental to the practical and commercial stage.

"Stippling" the glass, either inside or out, with whitewash is unsightly. If stippled inside, the composition is liable to be washed on to the plants by syringing; if stippled outside, it is liable to be carried away by rain. The adhesive quality of the whitewash may be increased, but against this advantage we have to balance the disadvantage of increased difficulty in freeing the glass and wood-work from the whitewash when required. A very good composition for the purpose, however, when stippling is the only process considered desirable, is a paint composed of white-lead thinned with turpentine to the required consistency. It must be noted, however, that the first frost will usually clear away most of this paint, if it be applied to the outside of the glass.

TEMPORARY SHADING.

In shading by means of blinds, avoid complicated mechanism. Have the blinds made as simple, consistent with efficiency, as possible.

Contrivances for transmitting the motion of blinds to some distance; pulleys and wheels worked by chains; mysterious-looking double-acting rods and bevel pinions; all these may be very pretty to look at, but are almost certain to break down at the first unexpected storm of hail, rain and wind. Or even if these contrivances survive such an ordeal, they will not be so likely to escape from the quieter but severer influence of continued moisture and atmospheric action.

Interior or exterior vertical shading in conservatories is frequently effected, in an easy manner, by Venetian blinds, or, especially if the area to shade be large, by ordinary or spring roller blinds. South African grass curtains are also applicable for this purpose. They are artistic, light, and are not injured by sun or rain. In growing-houses, where the roof is brought as near the plants as possible, and the front lights are very short (not more than 2 to 3 feet in height), vertical shading is generally unnecessary. Roof blinds, therefore, claim the greater part of our attention. If the outside of roofs be shaded with roller blinds, let them be made so that the whole apparatus can, without much trouble or unfitting, be lifted off and placed in a dry place in winter. Ridge weather-boxes, into which blinds may roll, afford excellent protectors during the weather when blinds are required almost every day; but as protectors for blinds during the winter they are snares. By all means let the boxes remain, but remove the blinds on the approach of the season when they will not be required. If left in the box all the winter, the wet drifts in, the blinds rot, quietly get out of order, and are found useless just at the moment when they are most urgently and unexpectedly required.

A simple roller blind is the best adapted for roof shading. This blind is fastened to a spline or rod held inside the longitudinal box at the ridge of the roof. When fully open, the blind hangs down to the distance required, and is fastened along its lower edge to a roller. If the roller be caused to rotate, it rolls the blind up the roof with the minimum amount of friction. To actuate this roller, there is sometimes fixed to one end a broad flanged wood pulley, round which is coiled cord. One end of this cord passes over a small pulley at the ridge of the roof, so that when the cord is pulled, it uncoils itself from the flanged pulley, and, in the act of uncoiling, rotates the roller and winds up the blind. This method, although simple, often causes the blind to be coiled up irregularly, by allowing the end of the roller opposite the pulley to wind up the blind very loosely. A much better method of actuating the roller is shown by Fig 87.

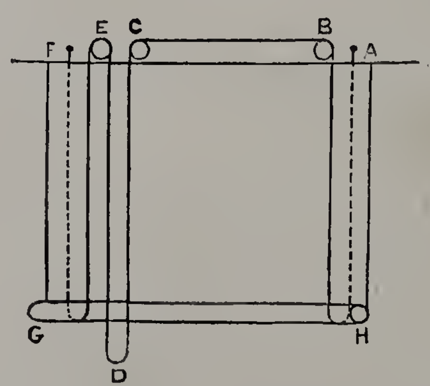


Fig. 87.—Plan showing mode of actuating roller blind.

This illustration represents the plan of a blind open on a roof, the edge being at F A, the roller G H being at the lower part of the roof. One end of a cord is fastened to the ridge at A, passes under the blind to the bottom, round the roller, over the blind, round a pulley at B, then to another pulley at C, over the blind, and sufficiently near the ground at D to be within easy reach of a person; over the blind to E, round a pulley, over the blind, round the roller, and finally behind the blind to a fixed point F. Upon pulling the double cords hanging at D, the roller G H will rotate and wind the blind up the roof. If there be an inclination for one end of the blind to rise quicker than the other, this irregularity can be easily adjusted by pulling one of the double cords at D more than the other. The double cord may be brought down at any other point along the blind than D, without altering the efficiency of the contrivance. Of course where top ventilation exists by hinged rising lights, blinds cannot be carried right up to the ridge, but must stop short, and have their protecting box placed just below the top ventilators. Roofs possessing transverse ventilators (parallel with rafters) can of course be provided with blinds merely in the spaces between the ventilators. Spring blinds cannot be recommended for outside work. They are certain, sooner or later, to get out of order.

It is so seldom that blinds can be fixed inside roofs, by reason of the obstructions caused by training wires, tie rods, vines, plants, &c., that it is needless to discuss this form of shading. Added to which, if it were thoroughly convenient to place blinds in this position, they would defeat, to a large extent, their original purpose; for they would allow the excessive solar heat rays to reach the interior of the house, instead of preventing their entry before their arrival at the glass.

In many instances the most convenient blind is one furnished with rings round its extremities, so that it may simply be fastened to semi-circular "shop front" hooks, and screwed into the wood-work where required. Such blinds present no parts which can get out of order by atmospheric exposure; they are easily and, if the establishment be not a very extensive one, rapidly put up and taken down; and occupy but little room for storage. In fact, in the case of many conservatories in which no part of the roof forms a rectangle, it is absolutely necessary to make blinds in this way. Of course there is a danger that a gardener may sometimes neglect to put up a blind of this description in consequence of the extra labour involved; but when he sees that such extra labour is inevitable, no one will so cheerfully perform it as a gardener.

One of the best materials for ordinary outside blinds is the No. 4 quality of tiffany. As the question of shading refers to the total exclusion as well as the moderation of the sun's rays, it may be as well to remark here that light requires to be excluded from mushroom-houses and fruit-rooms. So that if these structures are provided with windows, they should be carefully shaded by sliding or other shutters.

LIGHTING.

GROWING-HOUSES seldom require to be lighted by artificial means. Conservatories, winter-gardens, and floral-rooms, however, frequently require to be lighted on dark evenings. The available means for lighting are candles, lamps, gas, and the electric light.

CANDLES AND LAMPS.

These may generally be used without detriment to plants, and in many instances the light they yield will be all that is desired.

GAS.

Every one has a wholesome dread of gas in a conservatory. For the products of combustion and the dry heat evolved, are extremely injurious to plant life. But candles, lamps, and the electric light are obviously inapplicable to many conservatories, and there can be no doubt that, of all illuminating agents, gas would, in usual cases, if other things were equal, be employed.

Numerous plans are adopted for enabling gas to be used for lighting purposes without injury to plants. Sun-burners are constructed in such a manner that a column of extremely rarified air is utilized for conveying the products of combustion direct from the burners into the external air.

Globes are made to contain a smaller number of burners, combustion being supported by external air conveyed in a subsidiary shaft or tube, to the burner. But with most of these methods a sudden gust of wind is liable to reverse the direction of the ascending column of air, and send a puff

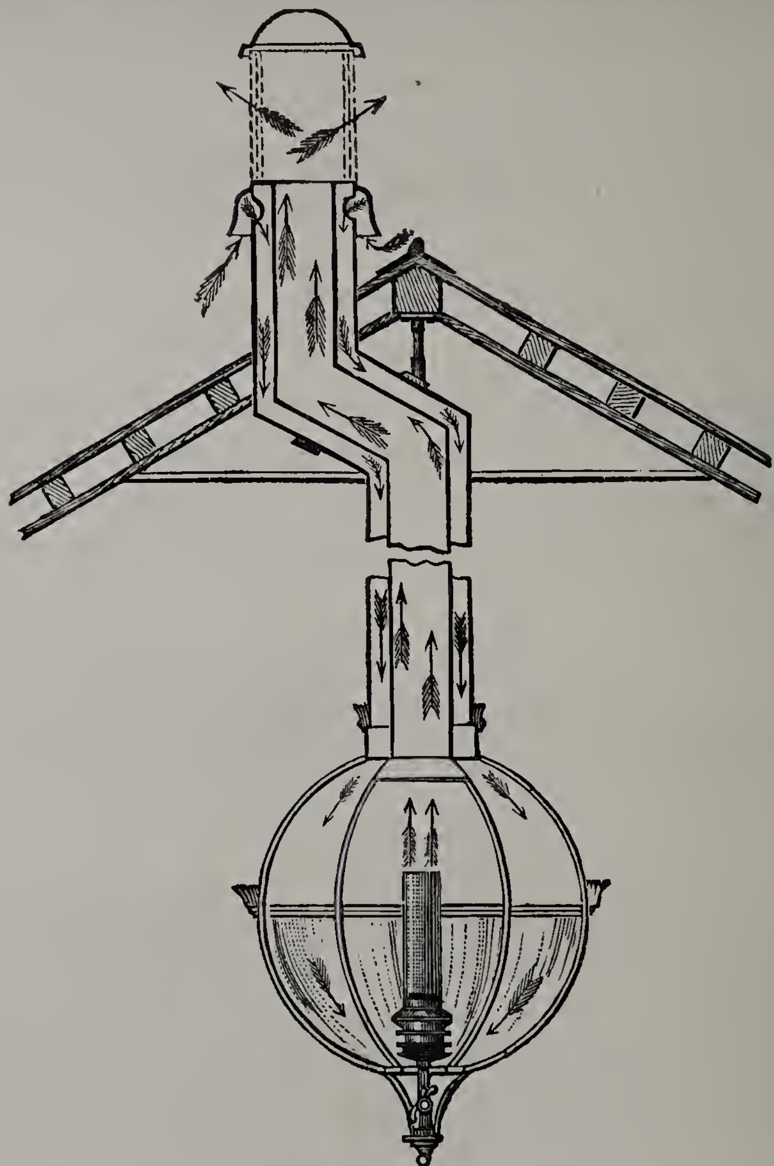


Fig. 88.—Sugg's patent self-ventilating light.

of noxious fumes into the building; a result which would produce an extremely slight inconvenience to an assembly of people, but which would work havoc amongst plants.

The best system of gas-burner for conservatory purposes, which the author has yet been able to discover, is that shown in Fig. 88.

This engraving represents a globe containing an argand burner, suspended from the roof of a building. The burner is enclosed and remains hermetically sealed to the atmosphere of the room. By noting the direction of the arrows, it will be seen that the column formed by the hot air and products of combustion ascends direct from the burner, through a central tube, and passes into the open air through a treble perforated wind-guard, in order that no down-draught, even in stormy weather, may take place. The external fresh air is fed to the flame through the annular space formed by a shaft enclosing the central tube. Of course, such a burner does not raise the temperature of the atmosphere in the apartment lighted. This point, however, is not of so much importance in a conservatory as in a dwelling-house. Such a globe as that shown, 20 inches diameter, would be a proportionate size for a 30-candle argand burner. A 26-inch globe would suit a 50-candle burner.

ELECTRIC LIGHT.

If recent investigations can be taken as a criterion, the electric light may be considered to have a powerful influence upon plant development. The subject, however, is yet in too crude a state to enable us to profit by the electric light for horticultural growing purposes. It is only as an illuminating agent that we will speak of it here. That it does not vitiate the atmosphere in which it was exposed; that the heat it radiates is insignificant; and that by its light colours are seen to almost as great an advantage as by daylight, render the electric light peculiarly suitable for winter gardens, &c., where the area to light is large and where the source of light can be placed high above the line of sight.

One arc-regulator lamp of 4,000-candle power, driven by an A-size Gramme dynamo electric machine, absorbing 2½ indicated horse-power, the lamp placed about 20 feet above the ground line, would illuminate about 500 square yards to a degree of intensity equal to having a gas jet within two or three feet; or if placed 30 to 40 feet high, would illuminate about 2,000 square yards in such manner that newspaper could be read with comfort over the whole area.

Sufficient is known to enable us to state that such lights as the foregoing can be supplied on contract at the rate of 6d. to 8d. per light per hour; supposing, of course, that the lights are burnt at least during fifty hours a week. Where an engine, mill, or turbine, is used on the estate for supplying power for pumping purposes (as described in "Water Supply") the same power can easily be made available for working the electric light. In this case the lamps may be placed at any distance up to half a mile from the source of power without rendering the cost excessive. Beyond this distance the wire conductor would require to be much thicker, and consequently more expensive, in order to overcome the resistance of the long circuit.

It is difficult for any one who has not seen the electric light in a winter garden, to form a conception of the beautiful effects produced by light and shade. The deep shadows which are so objectionable in many applications of the electric light, have a marvellous effect when they throw into vivid relief the delicate tracery of tree-ferns, palms, &c.

FORCING-BEDS.

THESE are of various kinds, and are used for various purposes, but the principles involved are identical. The main feature in them all is the propagation, bringing on for show-houses, and forcing of vegetables, flowers, and fruits, by treatment of soil as distinguished from treatment of atmosphere. That is to say, by raising the temperature of the soil round the roots and imparting moisture to this soil by systems of vaporizing, as distinguished from the direct development of stems and foliage by the heating and vaporizing of the atmosphere.

Fig. 89 shows one of the most approved forms of forcing-beds.

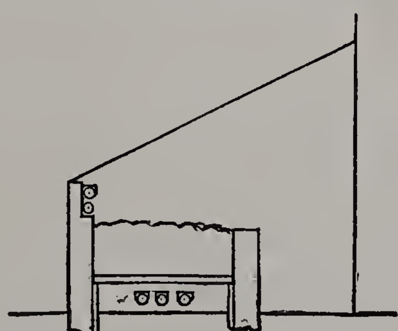


FIG. 89.—Section of forcing-bed.
Scale, $\frac{1}{8}$ inch = 1 foot.

Forcing-beds may be heated by fermenting materials, by flues, or by hot-water pipes. As the first does not come within our province, and the second we consider obsolete, we shall treat of the third method only.

The retaining wall of the house, with an additional dwarf wall, form a receptacle for the soil or compost into which the roots enter, or the pots are plunged. These two walls are thickened near the bottom to form ledges for the reception of supports to retain the soil. Below come the pipes for heating the bed. These pipes may be used with or without vaporizing contrivances. For vaporizing purposes, such pipes may either be fixed in a tank; or a trough may be cast on some of them; or they may be ordinary pipes with a portable zinc or other trough fitted upon them. Sometimes the projections inside walls are dispensed with, the space round the pipes filled with rubble, and the soil placed directly on the top. It will, however, frequently be found advisable to have an air space round the pipes for various reasons. Firstly, the pipes are more accessible, especially if they have vapour troughs or pass through a tank, and the water requires renewal. Secondly, vaporizing can be effected without the necessity of pouring water on to the soil before it can turn into vapour. Thirdly, cold air inlets can be more easily provided in the outer wall; or outlets can be provided in the inner wall, when hot air requires to be drawn from the neighbourhood of the forcing-bed pipes into the interior of the house, without first passing through the bed. Many beds are constructed in this way for the sake of economy; as the same pipes which pass under the beds can supply atmospheric as well as soil heat. A disadvantage, however, of this system is, that although it is easy to moderate the atmospheric heat, it is very difficult to moderate the soil heat and leave the atmospheric heat untouched. It is always advisable, whenever possible, to have the means of independently heating the soil and the atmosphere. In Fig. 89 the atmospheric heat is provided by pipes placed near front lights, one pipe of which can be provided if necessary with a vaporizing trough. It may, of course, be convenient to place these atmospheric heating pipes in the path; at the back; or on the top of inner retaining wall; in addition to or instead of the position shown in the figure.

These forcing-beds may be applied to any shape of house. They may be used in a lean-to house, as shown in the figure; or in three-quarter span-houses; or in comparatively narrow span-houses, when there can be a bed on each side, next the glass, and a walk up the centre (or a bed only on one side, with staging on the other), or they may be used in wider span-houses, in which there is space for a bed (or staging) on each side, next the glass, two paths and a central bed (or stage). Or forcing-beds may be in their simplest form, viz., in a row of garden frames or pit-lights, in which the only access is by sliding or lifting up one of the lights.

In some cases solid bottoms are recommended for forcing-beds. They certainly enable the space round the pipes to be kept clean and free from soil, and also maintain the bed moist, by preventing the moisture from so easily draining from the bed, but we must remember that we should not have a bad conductor between the hot-water pipes and the soil of bed. The more directly we can bring the hot air radiating from the pipes in contact with the soil, the more easily will the latter be heated, and for this reason it is advisable to have a skeleton bottom to the bed. Where it is considered advisable to have a close covering over the pipes, on which to rest the soil, then zinc resting on supports at intervals, or even slate, is better than a close-boarded bottom. For, independently of wood rotting more easily than the other materials, other things being equal, the relative heat transmitting powers of the different materials are :—

Zinc	430	Brick	12
Slate	42	Fir	3

A good conductor of heat should therefore be placed between the pipes and the soil, where any solid intervening material is required. Iron is a better conductor than zinc, but iron rusts, therefore it is seldom used. For the same reasons a bad conductor of heat should be placed at the sides of the bed, where the heat requires to be retained and not dissipated. Therefore, for the sides of a bed, wood is better than brick, brick better than slate, and slate better than zinc. But as wood is apt to rot and is not so thick as brick, the latter is the best material which can be employed, especially as we have generally, at least, one existing brick wall which can be utilized. It is scarcely necessary to state that forcing-beds of all kinds should be properly drained.

In connection with forcing-beds, striking boxes are sometimes used. These may either be a portion of the bed covered by a light framework and glass, or a separate box, having a zinc or slate bottom, plunged in a bed, or placed over pipes, and having means for vaporizing.

BORDERS.

CONDITIONS.

IN the treatment of the roots of vines, &c., there are several main points to be kept in view, and these points will regulate, to a certain extent, the mechanical construction of the border. The drainage must be perfect. The roots must feed upon only such compost or soil as is intended for them. In some cases this soil must not be exposed to a cold atmosphere.

Fig. 90 will show how these conditions may be fulfilled.

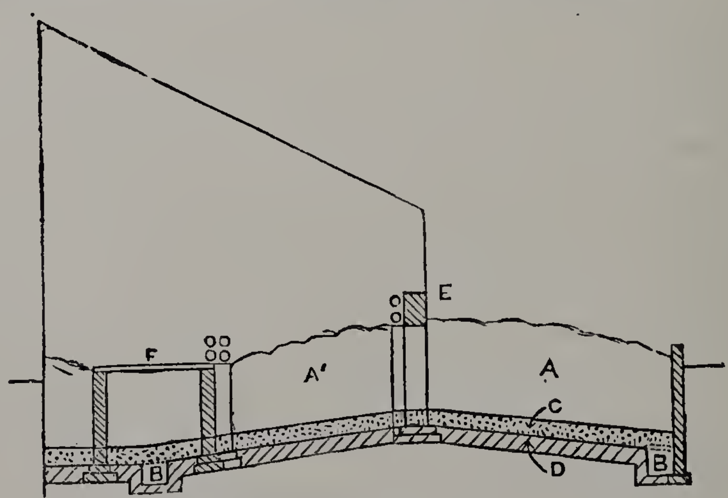


FIG. 90.—Section of border.
Scale, $\frac{1}{8}$ inch = 1 foot.

A Outside border. *A′* Inside border. *B* Drain. *C* Rubble. *D* Concrete.
E Front wall on arches. *F* Path supported by piers at intervals.

DRAINAGE.

If the ground slope, the soil be light, and wet can be carried away in a natural manner, artificial drainage of a special nature may be unnecessary, and the bottom of the border may be formed of a layer of rubble or stones and brickbats, which will not only assist in the drainage of the border, but prevent the roots having access to any other soil than that in the border. If the ground be heavy, lies low, or there is the slightest likelihood of the border being naturally undrained, careful artificial drainage must be carried out. In this case the best manner of constructing the border is to lay down first a layer of concrete sloping downwards towards the outer retaining wall, where, at the lowest point, there should be a longitudinal drain. Then a layer of rubble, with perhaps some small drain-pipes arranged transversely to the border; then turf, to prevent the compost filling up the interstices of the rubble; then the soil of the border proper. So important is the question of drainage that as much of the border as is possible, especially with heavy soil, should be above the ground line. If it be not convenient to slope the concrete foundation in so great a proportion as is shown by the figure, then efficient transverse drains must be laid. The thickness of the layer of rubble may vary from 6 to 12 inches in accordance with the ease or difficulty of draining.

DIMENSIONS.

The proper depth of a border is a point regarding which opinions and circumstances vary, but 2′ 6″ to 3′ 0″ may be considered a good average depth.

The width of the border will also vary according to what is grown in it and other circumstances, but it may roughly be stated that for vines in the open air, against a wall, 10′ 0″ to 11′ 0″ is a good width, whilst for vines in houses, the borders may have a total width equal to the length of the rafters.

CONSTRUCTION.

It will be noticed in Fig. 90 that part of the border is inside and part outside the house; the front wall being built on arches to enable the roots to run both ways. Or the alternative method may be adopted of suppressing part of this front wall, and obviating the necessity for arches, by supporting the mullions on light iron pillars and filling in the spaces between the mullions by slate slabs. (See "Brick-work," p. 91.) In some cases it is considered advisable to have the entire border inside, especially for early vines, in order that root action may not be checked by the exposure of part of the border to the cold air. In fact it is sometimes thought necessary, not only to thoroughly protect the top of the border, but to provide bottom heat by fixing hot-water pipes in a chamber under the border or in the manner shown in article "Forcing-Beds," p. 153. For general purposes, however, it is quite sufficient to construct the border as shown by Fig. 90. When necessary, the border may run right through the inside of the house up to the back wall, by the path being supported on piers at intervals; when that part of the border near the back may be utilized for wall-trees. Or the border proper may end at the outer edge of the path by stopping the concrete and rubble against a wall built to support this side of path. A subsidiary border may then be made next the back wall (and under path) for wall-trees; or this space may be utilized by shelves. Sometimes transverse walls are built through the border in order to prevent the roots of one vine from interfering with that part of the border devoted to an adjoining vine; or when different root treatment but identical atmospheric treatment is required for consecutive vines.

The preceding figure shows a path near back wall. If the house be wide and a path required near the front, a wood trellis path is the best to place over the border.

GENERAL NOTES.

Precisely the same remarks will apply, so far as borders are concerned, to span, or forms of houses other than lean-to. The piers or dwarf wall for supporting edge of path may be utilized for sustaining some of the hot-water pipes, and others may be fixed by thickening the piers carrying the arches of front wall. Or the front pipes may be supported on piers at some little distance inside front wall when the stems of vines would otherwise be too near the pipes.

The formation of the soil of the border being a question of cultivation rather than construction, it will not be discussed in this volume.

When borders are formed outside, as well as inside, it may sometimes be advisable to cover the outside portion with tarpaulin, litter, ferns, matting, roughboarding or other materials, as a protection against frost and cold rain.

It is not always judicious to make the whole of the border at one time. Many gardeners consider that making the border only in proportion as the vine-roots grow, not only husbands the resources of the border, but tends to increase the fruitfulness of the vines.

This, however, only applies to the absolute soil of which the border is composed. The retaining walls, piers, rubble, drainage, &c., for the whole border, can be more easily constructed at one time than in parts.

PATHS.

PAVEMENTS for the interior of horticultural buildings are of two kinds, permanent and portable.

PERMANENT PATHS.

These may be constructed of stone, slate, bricks, tiles, concrete, or cement.

Stone paths are very durable and substantial, but do not possess the advantages of slate paths, which do not absorb the moisture and are easily cleaned. Slate slabs, however, are much more expensive than the ordinary stone paving slabs.

Bricks are sometimes used, but can scarcely be considered a very satisfactory material for paths. They are apt to wear irregularly, and the joints to open, unless grouted with good cement. Vitrified blue bricks, as employed in stables, are also occasionally used. These have bevelled edges, so that, when joined to each other, a series of small cross gutters are formed. In forcing pits or places where the floor would be liable to be constantly receiving moisture, this description of paving may prove very useful, but its appearance is unfavourable and it is not very pleasant to walk upon.

Tiles are the most favourite materials for constructing paths for horticultural buildings. Builders' ordinary 6″ or 9″ red and buff Staffordshire tiles, carefully laid, diagonally, in cement, upon a good bed of concrete, form, at reasonable cost, a very neat, durable, non-porous, easily-cleaned, agreeable-looking path. If badly laid, by inexperienced workmen, they are a never-ending source of annoyance. The joints gape, the tiles wear loose, become ricketty, look untidy, and nothing short of taking them up, levelling the bed and properly re-laying, will remedy the mischief. So much for tile paths in ordinary growing-houses. In conservatories, &c., in which geometric patterns and a superior quality of tiles are required, Minton tiles as well as the more elaborate mosaics are frequently used. (See pp. 64 and 65.)

Concrete paths are sometimes used, but as a smooth surface cannot easily be obtained and the cost is almost as much as an ordinary tile path, concrete, by itself, can scarcely be recommended.

Cement forms a very good material for paths, but it requires a bed of concrete to be floated upon, and the cost is not much less than a good tile path, therefore the latter will generally be found the more preferable.

Edging is naturally formed in stone, slate, concrete and cement paths by the material employed; but in tile paths some protection is required at the edge. If this be not supplied by dwarf walls, or a grating covering hot-water pipes, a curb must be provided in the form of either a plain or moulded section of stone; strips of slate laid edgewise; or expressly made edging tiles, of which there are several standard patterns.

PORTABLE PATHS.

These are required for placing over vine or other borders which would receive injury by being trodden by feet. Although the weight of a person upon a border is the same if he walked upon the soil as if he walked upon a path laid upon the soil, yet, in the latter case, his weight is distributed over a very much larger area than in the former. A convenient lattice wood path for this purpose is easily constructed of battens $4\frac{1}{2}'' \times 1\frac{1}{8}''$, laid transversely on quartering, with $\frac{3}{4}''$ spaces between, and a neat nosing at each edge. To impart solidity to it and to increase the permanency of its character, such a path may be supported on small brick piers at intervals. In this way, although not so durable as slate, stone, or tiles, it forms the cheapest permanent as well as portable path which can be made.

Ornamental perforated cast-iron slabs can be used for paths instead of the above lattice wood-work, but iron, although much more durable, is more costly, will rust, and is slippery and unpleasant to walk upon.

Paths, either in iron or wood, enable the borders to extend much farther than with solid paths, and thus, by increasing the effective width of border, often enable the structure to be built narrower than it otherwise could be.

GENERAL NOTES.

Although houses may be paved with tiles or other solid material, they are frequently covered by a portable lattice wood path, which serves the same purpose as the old-fashioned pattens did in the laundresses' yards. Paths in conservatories or floral rooms are fast giving way to paved spaces, in which a table and a chair or two are appropriate and convenient. (See "Conservatories," p. 63.) When solid material paths are laid, it is advisable that the question of drainage should not be forgotten. Moisture from condensation and watering is apt to fall upon paths, and provision should be made, by a slight fall, so that the wet is not allowed to lie in pools.

In combinations of houses it is advisable that the paths be all on the same level if possible; and when an entrance is made from a drawing-room into a conservatory, if there be no raised door-sill, the path of the latter should be about 2″ below the level of drawing-room floor, in order that there may be no possibility of water draining from the conservatory into the drawing-room.

The widths of paths vary according to circumstances. A 2′ 6″ path is sufficiently wide to walk upon in all growing-houses where there are no staging, beds or dwarf-walls, but if there be any of these latter rising to 2′ 6″ above ground line, then the path may be a little wider, say 2′ 9″ or 3′ 0″. If a house be small and every inch of available area required, then a 2′ 6″ pathway, even with obstructions rising on each side, will doubtless be found sufficient. On the other hand, in extensive ranges of large plant-houses, 3′ 6″ between stages is not too much for a convenient pathway. The width, as well as the position of paths, will depend, however, very much upon the arrangement of staging.

CONDENSATION AND DRIP.

CAUSES.

AS shown in section "Hygrometer," the atmosphere always holds, in invisible suspension, a varying quantity of moisture. The higher the temperature, the larger the quantity of moisture is the air capable of thus holding. It therefore follows that, supposing the atmosphere at a high temperature has been allowed to take up sufficient moisture, a fall in the temperature means a condensation and a consequent deposit of some of such moisture. The moisture on the outside of a glass, into which cold water has been poured in warm weather; dew; and fog; are all apposite illustrations. It will, therefore, be seen that the greater the difference between the temperature of air inside and that outside hot-houses, the greater will be the liability for moisture to condense on the inside of the glass, and either drip or run down to the lower part of the roof. Ample ventilation will do much towards carrying off superfluous moisture into the outer air and preventing drip, but it may frequently happen that a higher temperature requires to be maintained than is consistent with any large amount of ventilation. The lower the pitch of roof, the greater the probability of drip. Of course, it is needless here to refer to the disadvantages of drip on plants. The condensed moisture is cold—having parted with some of its heat in order to condense. If the moisture condense on iron-work, especially if the iron-work has not been kept properly painted, it is not only liable to rust, and thus quickly wear out, but some of the rust is carried on to the plants.

CONSTRUCTIONAL PREVENTION.

While recognizing the liability of condensation inside hot-houses, means should be employed for neutralizing, as far as possible, its prejudicial effect on plants, on iron-work, and on wood-work, by giving to sash-bars and rafters such a section that drip is least likely to occur; by facilitating moisture running down to the bottom of roofs; by letting the plate against which the sash-bars, rafters, or roof-lights rest have a bevel top; by collecting this condensed moisture, if thought desirable, and the expense is not a consideration, by a system of inside gutters; and by keeping both iron-work and wood-work well covered with paint. A ridge and furrow roof is very liable to drip by reason of the number of horizontal gutters it contains. Sir Joseph Paxton obviated, to a great extent, the drip from such a roof, by cutting little sinkings or subsidiary gutters on each side of the plate forming each valley-gutter, but this weakens the material and is not always efficacious. Again, a house may be constructed so that drip cannot possibly take place from the framework, yet the moisture condenses on the glass and persistently refuses to run to the sash-bars, but either drips straight from where it condenses or runs down the middle of the pane and drips from the lap.

Independently of drip in a house being caused by condensation, it may be the result of rain dripping through the laps; through the joints of ventilators when either closed or opened; or through the ventilating openings themselves. A very low pitch of roof (much less than 26°) will will be almost certain to cause the first; the second should be obviated by constructing the ventilators in such a way that the joints have no liability to admit wet under any circumstances; and the third has been referred to in the article on ventilation.

OUTSIDE DRIP.

Besides drip inside houses, there is sometimes drip outside houses, resulting from a defective system of gutters and roof drainage. The only case where drip is advantageous, is when wood or other framework rests on a brick wall. In this case it is not advisable to allow the rain which beats against vertical glass-work, or any condensed moisture, to run down on-to the brick-work. A small groove is, therefore, made underneath the overhanging part of the plate resting on the brick wall. This groove arrests the wet and causes it to drip on to the ground instead of running down the wall.

MISCELLANEOUS NOTES ON CONSTRUCTION.

IN the sections under this heading will be given a few notes on constructional details not given elsewhere.

GUTTERS.

Galvanized sheet-iron is sometimes used for these instead of cast-iron. The saving in cost is not much, and those made of the former material are apt to "buckle," and will not permit a ladder to be placed against them. There is no objection to forming a wood gutter by making a sinking in the eaves plate, provided the latter is of ample dimensions. Such a gutter need not necessarily be lined with any metallic material, as it will be found, in consequence of its thickness, to last as long as, if not longer than, any other part of a wood house. Some makers, however, prefer to line such gutters, in which case care should be taken that there be no possibility of moisture collecting between the wood and the lining. Usually, when a roof descends to the top of a wall, the plate upon which the roof rests, has its outer edge level with the face of the wall; consequently, any gutter fixed on the plate will overhang the wall. Sometimes, however, the plate is placed on the wall so that the outer edge of the gutter, when fixed, does not project over the face of the wall. The former is the better method of the two, but the latter is sometimes necessary when it is desirable that a gutter should not project over a party-wall. (See "Legal.") Gutters should, when possible, have a fall of about 1 inch in 10 feet. This cannot, however, always be done. Whenever the gutter more nearly approaches the dead level, so down pipes should be at more frequent intervals. There should, if possible, be no valley-gutters next the brick-work of a dwelling-house. (See p. 69.) If it be absolutely necessary that a roof should slope downwards towards the wall of a dwelling-house, let the valley-gutter be a broad lead flat, well flashed, and sufficiently wide for a man to walk easily, and clear away any snow, leaves, or other obstruction to the drainage. Down pipes should discharge over open gratings, in order, more easily to keep the pipes and gutter free from obstruction.

THE SCANTLING.

This should not be too heavy, or it will afford solar obstruction, present a large area to atmospheric action, will warp, sag, form crevices for insects, &c., and easily rot; neither must it be too light, or it will quickly wear out and will not be sufficiently strong to permit workmen going on the roof to effect repairs, without shoring up inside—a procedure which should never become necessary.

ROOFS.

These should be well "tied," so that there may be no lateral thrust on the walls or side lights, all strains should be distributed so that there may be no pressure whatever except a vertical one. The author has seen more than one straight-roofed as well as curvilinear house, in which diagonal wood struts had absolutely to be fixed outside the walls supporting the house, or the brick-work would have been forcibly pushed down. It is essential that ventilators in the roof as well as in other parts of a house, should be so constructed that rain will not drift through at the hinges when either closed or partially or wholly open. The sash-bars and rafters should be of sections the least conducive to drip, and the plate on which the roof rests should have a bevelled top so that the water of condensation may not remain on it.

THE FURNITURE.

This should all be substantial and durable. It is false economy to have the cheapest locks, hinges, gearing, set-opens, door-handles, latches, cord, &c., which can be procured. It is always worth spending a few shillings extra in having good brass mortice locks, rather than cheap rim locks which will rust and become worse than useless in a fortnight after they have been first exposed to the peculiarly trying atmospheric influence of a hot-house. Ventilator butts and other hinges, exposed to continual moisture, should be of brass, not iron.

Points of construction are also necessarily mentioned, directly or indirectly, in various places throughout the book.

VARIOUS MODES OF HEATING.

HEATING is such a gigantic subject, that if treated in any degree exhaustively, it would extend far beyond the limit which can be accorded to it in the present volume.

We propose to mention those systems which may be, but are not usually, employed for horticultural heating; give the salient points of each; then state some of the principles involved in heating; describe the system which is most usually adopted; and discuss, seriatim, the various component parts of that system.

For horticultural purposes artificial heat may be obtained by fermenting materials; flues; hot-air stoves; lamps; gas-stoves; high pressure hot water; steam; and low pressure hot water.

FERMENTING MATERIALS.

These may be considered to belong to the province of the gardener or cultivator, rather than to that of the mechanician, and will therefore not be discussed here.

FLUES.

Flues are simply connecting channels between a furnace and a chimney for conducting hot air in the vicinity of the space to be heated. The hot air, in its passage from the furnace to the chimney, heats the materials of which the channels are made (usually bricks), which in their turn heat the stratum of air next them. This air rises, colder air takes its place, is heated, rises, and the process is continued, as long as the furnace supplies heat, and any part of the surrounding atmosphere remains unheated. The hot bricks also radiate heat to surrounding objects.

Flues are rapidly becoming obsolete, chiefly for the following reasons:—The joints are apt to crack and the products of combustion to enter the house to be heated, to the detriment of the plants. It is possible for a flue to be heated to 800° Fahr., when such a concentration of radiant heat in the vicinity of the flue may scorch the plants. Besides the concentration of heat, an unexpectedly high temperature may mean an excessive dryness of the atmosphere, to the ruin of the foliage, &c. Flues are incapable of having their heat moderated and manipulated with that delicacy which is so often required in various important horticultural operations. Flues are apt to be uncertain in action. Extensive combinations of houses cannot be heated successfully unless a large number of separate furnaces are employed; for the independent heating of several consecutive houses by a flue from one furnace is almost impossible. In fact, even if other things were equal, it is only reasonable to suppose and state that hot air cannot be under such effective control as hot water. Flues are apt to receive an interior coating of soot (a very bad conductor). This, if not constantly cleared away, would prevent the bricks from absorbing heat. A flue may be considered very wasteful of fuel when more heat is absorbed and radiated than is required.

On the other hand, the first cost of a flue, other things being equal, is not so great as that of an efficient hot-water apparatus. More heat is capable of being extracted from a given amount of fuel in a flue than in a hot-water apparatus. For, with proper manipulation, the air, &c., issuing from the chimney of a flue should not have so high a temperature as that issuing from the most economical hot-water boiler; as the greater area of surface in a flue should naturally absorb more heat from the products of combustion than the smaller area of surface in a hot-water boiler.

The favourable points in flues, however, are much more than counterbalanced by the unfavourable points.

HOT-AIR STOVES.

Of these there are numerous kinds. They may be split up into three groups ;—Those which discharge the products of combustion and heated air into the apartment to be heated—Those which are provided with a chimney for carrying away the products of combustion and radiate heat from the body of the stove—And those which cause fresh external air to come in contact with the radiating surface of the stove, become heated, and pass into the apartment. Many of the objections against flues may be raised against stoves for all ordinary horticultural purposes. The heat is concentrated not distributed; excessive dryness and heat may exist; in some there is the liability of injurious products of combustion to escape into the house; they are certainly not so economical in fuel as the ordinary flues; heat generated by them cannot easily be manipulated or controlled.

For small houses, however (from which it is necessary simply to keep out frost), harness-rooms, stables, &c., where hot water would be too elaborate and costly an apparatus, a fuel-stove may be used, destined to burn a prepared charcoal, such as Joyce's Patent Fuel, which is not supposed to generate any fumes injurious to plants; or, what is better, a slow combustion stove, of which Fig. 91 is perhaps the best type. This stove has a fire-clay lining and base, no open grate but a lower slide for the entire control of the admission of in-coming air. A chimney must be provided for this stove.

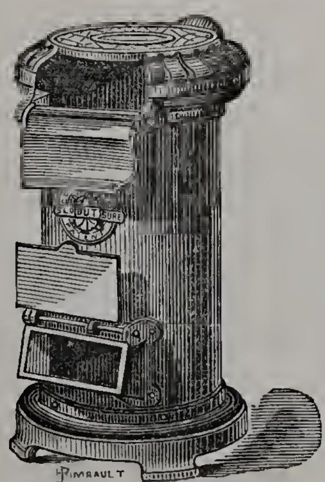


FIG. 91.—Portway's patent slow combustion stove.

LAMPS.

Paraffin and other lamps are occasionally used for heating purposes, but they can seldom be advantageously employed except in the smallest of houses. Some of the lamps give an unpleasant smell.

GAS STOVES.

Gas stoves which allow the products of combustion to enter a house are perfectly inadmissable for horticultural work. The cost of maintenance of a gas-heated boiler is very high, and although such an apparatus is sometimes used in a small green-house, chiefly by reason of the insignificant amount of attention required, gas certainly cannot be recommended for hot-house heating, until means are devised by which it can be made to produce heat much more economically than by any apparatus yet invented. (See section on "Fuel.") Under any circumstances, extreme care is necessary in the manipulation of a gas stove for horticultural purposes. So deleterious is the effect of the products of combustion of a gas stove on plant life, that the author has known several instances of such products of combustion being drawn into a house through the ventilators, even when the gas apparatus itself was fixed outside the external walls.

HIGH PRESSURE HOT WATER.

Water, when heated in a vessel open to the atmosphere, can never attain a higher temperature than 212° Fahr. If, however, water be heated under pressure, it can attain a much higher temperature. The high pressure hot water system consists of a series of wrought-iron pipes containing water and hermetically sealed, in which the water is heated and circulates at a temperature of 300° to 400° Fahr. The circulating pipes are usually of small diameter. At the highest point of the system is provided a pipe, or rather receptacle, of larger diameter, to act as an expansion tube. In its unheated state the water is allowed to fill the pipes up to the bottom of the expansion tube. When fuel is applied, ignited, aud the temperature raised, the air in the expansion tube being more elastic than the water, allows the latter to expand and enter the tube. As the pipes forming the radiating surface are small and the temperature high, the heat is more concentrated than is convenient for horticultural purposes. As, moreover, the pipes have to resist a high internal pressure, there is danger from explosion as well as from combustion of materials in proximity to the pipes. This system, for the above reasons, is scarcely applicable for combinations of houses, and, in fact, is seldom used for horticultural work.

STEAM.

This system is very similar to the last described, with the exception that steam is employed instead of hot water. Steam, like hot water, is subject to the same general law that, in a certain ratio, the temperature is raised as the pressure is increased. Therefore, the same objections can be raised against heating by steam, as by high pressure water, with the addition that steam can seldom be used economically as a heating medium except where exhaust and waste steam can be employed, as in factories and buildings already using steam power.

LOW PRESSURE HOT-WATER HEATING.

This system, the most advantageous for horticultural purposes, is treated in detail in the ensuing pages.

LOW PRESSURE HOT-WATER HEATING.

GENERAL PRINCIPLES.

HEAT is transmitted by radiation, conduction, and convection. By radiation, when heat passes from its source to a given object without materially raising the temperature of the intervening atmosphere. By conduction, when heat is conveyed along the mass of a body. By convection, when heat is propagated by means of currents. The face of a person standing in front of a blazing fire is warmed by radiation. The handle of a poker, having the other end thrust into the fire, is warmed by conduction. The mass of water in a tea kettle is warmed by convection.

Radiant heat, as the name implies, like sound and light, is transmitted in straight lines and in every direction. The intensity of heat by radiation diminishes inversely as the square of the distance from the point of radiation. This law is the same as that of the radiation of light. Fig. 9, on page 14 very clearly illustrates this. Supposing at one yard distance, a certain quantity of heat-rays covers one square foot; at two yards the same rays would cover, not 2 but 4 square feet; at three yards, not 3, but 9 square feet; and at four yards, not 4, but 16 square feet. So that supposing at one yard, the intensity of the heat-rays falling on one square foot equals 1; at 2 yards, the intensity on the same area would be not $\frac{1}{2}$ but $\frac{1}{4}$; at 3 yards, not $\frac{1}{3}$, but $\frac{1}{9}$; and at 4 yards, not $\frac{1}{4}$, but $\frac{1}{16}$, and so on.

It may be useful here to give a table showing the comparative conductivity or heat transmitting power of various building materials.

TABLE XVIII.—THERMAL CONDUCTIVITY OF VARIOUS MATERIALS. (HURST.)

Material.	Thermal Conductivity.
Copper	1000
Iron	450
Zinc	430
Lead	230
Slate	42
Bath Stone...	25
Glass	14
Brick (Fire)	13
,, (Common)	12
Oak	4
Fir	3
Cork	2
Canvas	1

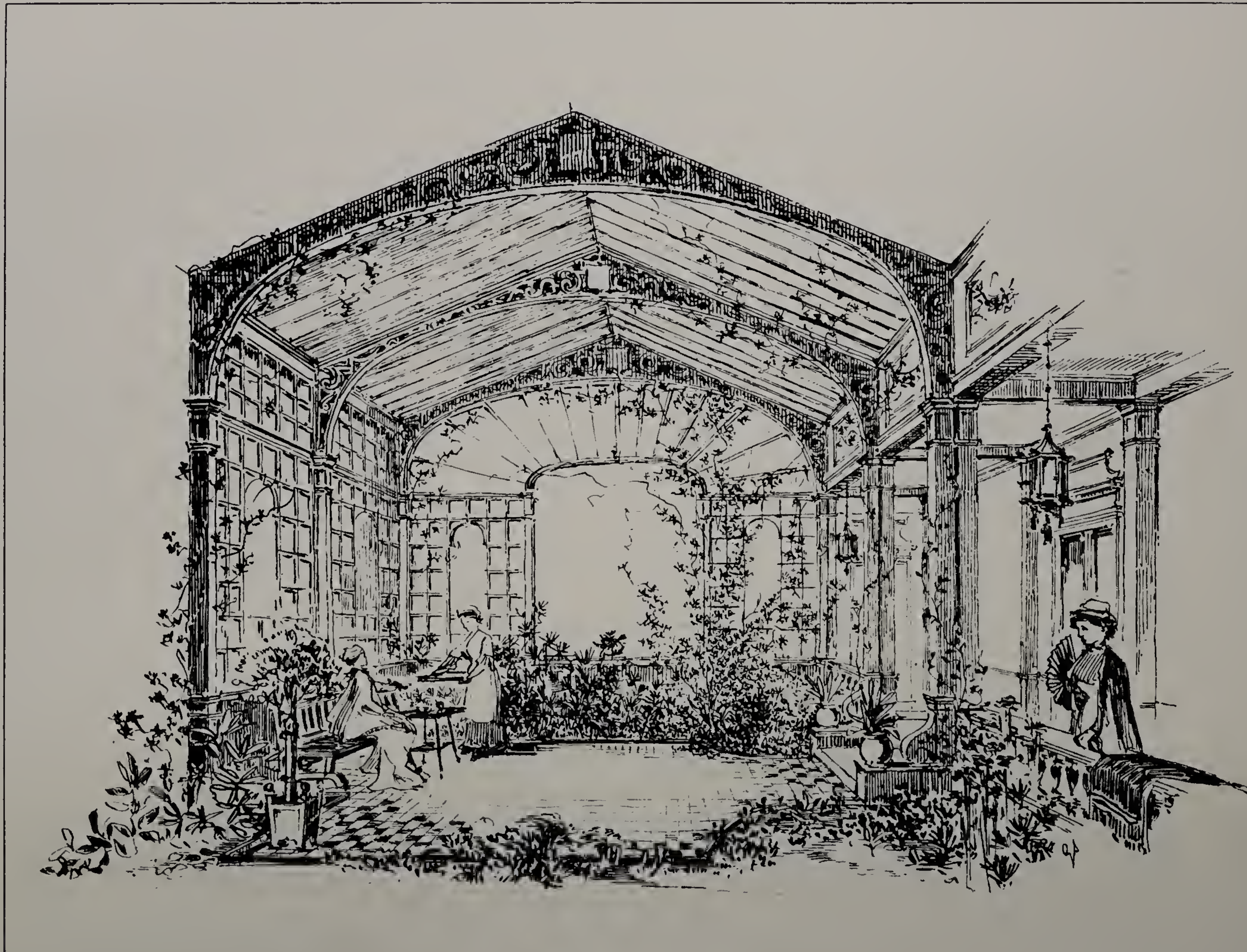
When substances having different temperatures are placed in proximity to each other, there is a natural tendency for an equalization of temperature to take place. Thus, other things being equal, and external influences excluded, two substances, having respectively the temperatures 60° and 90°, when placed together, will both have a tendency to assume the temperature 75°. That which receives heat quickly will naturally part with it quickly and *vice versâ*. So that other things being equal, the greater the cubical contents of a house, the more gradual will be the effect of sudden sunshine or frost. The smaller the house, the quicker can it be heated, but the more rapidly will it cool when the source of heat is withdrawn. The larger the cooling surface, in proportion to the cubical contents, the more quickly will heat be extracted from the interior.

Air and water are very bad conductors of heat. It is only when convective currents take place that heat is imparted to the mass. The influence of variations of temperature upon air is discussed in the article "Ventilation," p. 132. Much the same effect is produced by variations of temperature upon water as upon air. But while we see, according to Table XVII., that air, no matter what temperature it may have, expands when that temperature is raised; water must have 39·2° Fahr., or upwards, in order to expand when the temperature is increased. Below 39·2° water expands

TABLE XIX.—RELATIVE VOLUMES OF WATER AT DIFFERENT TEMPERATURES.

Temperature Fahrenheit.	Volume.	Temperature Fahrenheit.	Volume.
°		°	
20	1·0012000	122	1·01261
30	1·0003780	132	1·01527
40	1·0000000	142	1·01814
42	1·0000258	152	1·02120
52	1·0005123	162	1·02443
62	1·0014070	172	1·02788
72	1·002627	182	1·03148
82	1·004143	192	1·03526
92	1·005901	202	1·03922
102	1·007911	212	1·04333
112	1·010150		

upon *decreasing* the temperature. That is to say, water is at its greatest density and minimum volume at 39·2°. Table XIX. shows the volumes of water at different temperatures; the volume at 39·2° Fahr. being 1.



Omitting anything, therefore, in relation to water below 39·2° (say roughly 40°) we see that the same general remarks regarding the circulation of air will apply to the circulation of water. As, however, water is not so mobile a substance as air, we can manipulate the former in a much more precise and certain manner than the latter.

Hot water rises and cold water sinks, simply because their specific gravities differ; in other words, a certain bulk of hot water weighs less than an equal bulk of cold water, and when they are allowed to come in contact, the heavier cold water sinks, and in sinking pushes the lighter hot water upwards.

APPLICATION OF GENERAL PRINCIPLES.

In the application of the above principles to low pressure hot-water heating, two columns of water are employed. One column is always kept hotter than the other, consequently a systematic displacement of water is continually taking place, and what is called "circulation" is maintained. Fig. 92 represents a longitudinal section of the apparatus in its simplest form.

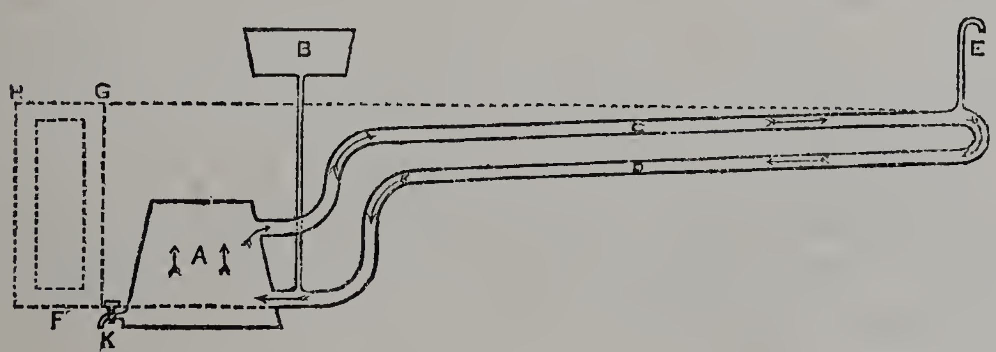


FIG. 92.—Longitudinal section of heating apparatus.

A shows the boiler or heat generator. C and D, pipes, which, with A, contain the two columns of water. By "two columns" must be understood vertical height only. That is to say, the two columns of water contained in A C and D are equivalent, roughly, to the dotted lines H F and G F; or the vertical difference between the top of the pipe C and the bottom of the pipe connecting D with A. K shows a tap for drawing off the water when required.

We will imagine A C and D are filled with water of the same temperature as the pipes and the surrounding air. No circulation of water therefore takes place. On applying heat to the boiler A, hot water rises in the pipe C, being pushed upwards by the cold water sinking in D. The pipe C absorbs heat from the water, radiates it to the atmosphere, and in doing so cools the water in C. But in the meantime the boiler A has been generating more heat, hot water rises in C, is cooled, sinks through D, and the process is repeated, as shown by the direction of the arrows, so long as A continues to generate heat and C and D have a temperature above that of the air or objects surrounding them. The expansion of the water which takes place, as part of it becomes heated, is compensated by the surplus space provided in the empty cistern B. In order that air may not accumulate in the pipes and impede the circulation, a small tube E, open at the top, is inserted in the highest part of the highest pipe C. As both B and E are open to the atmosphere, there is no internal pressure on any part of the apparatus, except that occasioned by the head of water. Therefore the temperature of the water can never rise above 212° Fahr. Although the water in a low pressure heating apparatus is not supposed to boil, yet it is liable to waste by evaporation; the expansion cistern B is therefore connected by a pipe with the lowest part of the boiler, and serves as a receptable for replenishing the water.

This system is safe, simple, reliable, capable of easy manipulation and delicate adjustment, and has, for horticultural purposes, the enormous advantage that radiation temperature can never exceed 212° Fahr. (or rather in practice 200° Fahr.).

CAUSES OF FAILURE.

There are a great many points which should be noted in connection with hot-water heating. A disregard of them will generally produce an entire failure in the apparatus. It is very usual, when an apparatus does not work properly, to jump to the conclusion that "something is wrong with the boiler." This, of course, may be the case, but the failure may arise from any one, or a combination, of many causes, amongst which may be mentioned :—

Insufficient quantity of radiating pipes.
Improper position " "
" " main pipes.
Obstructions in radiating or main pipes caused by air or dirt.
Air pipes fixed improperly.
Supply cistern " " "
Insufficient power of boiler.
Improper position " "
Improper setting " "
Incrustation " "
Improper stoking " "
Defective construction of chimney.
Deposit of soot in chimney, &c., &c.

All these, and many other points, will be raised in the following description of the various parts of a low pressure hot-water heating apparatus.

THE RADIATING SURFACE.

This is usually in the form of 2″, 3″ and 4″ pipes. As it is advantageous, for horticultural purposes, to have, within a convenient limit, the largest amount of water in proportion to the area of radiating surface, the 4 inch pipes are generally used as heating surface. The 2″ and 3″ pipes are more usually employed as supply mains. The proportion of radiating surface in 2″, 3″ and 4″ pipes is the same as their diameters. The 4″ pipe contains twice as much as the 2″, and the 3″ half as much again as the 2″. The amount of water contained in the same length of 2″, 3″ and 4″ pipe varies in a different ratio, viz., in proportion to the squares of the diameters. Thus, if a given length of 2″, 3″ and 4″ pipe be taken, the amount of water contained in each will be in the proportions of 4, 9 and 16 respectively. It must be remembered, however, that so far as anything which has to do with loss of heat is concerned, all calculations are based upon the area of radiating surface, and not on the contents of the pipes.

It is without question that wood, subjected to a constant current of greatly heated air, is peculiarly liable to combustion. In view of this, the Metropolitan Building Act (see article "Legal") specifies that no hot-water, hot-air, or smoke-pipe shall be nearer than a given distance to any combustible material.

The two principal points in relation to the radiating pipes are:—Quantity and position of pipes under varying conditions.

QUANTITY OF RADIATING PIPES.

As already explained, the temperature of the water in the pipes of a low-pressure apparatus can never exceed 212° Fahr., but in practical working the maximum temperature of the pipes may be taken at 200° Fahr. To obtain healthy vegetable growth it is not advisable that the radiating surface should be even so warm as this. 180°, or if possible less, should not be exceeded. Of course, this necessitates more pipe than if the maximum temperature of radiating surface were attained. But the slight extra cost (the cost of most of the fittings, &c., remaining precisely the same for the larger as the smaller quantity) would be more than compensated by the increased cultivating efficiency of the apparatus; and by the enormous economy in fuel which would result from driving the pipes at a moderate instead of a maximum temperature.

The amount of pipe required in a house, depends upon:—The cooling area of the glass-work—The temperature outside—The required temperature inside—And the temperature of the radiating pipes.

There are numerous formulæ given by different authorities to ascertain the amount of pipe required, but that determined, after many experiments, by Tredgold, is usually accepted as giving some of the best results.

First of all, it is necessary to ascertain the number of cubic feet to be heated per minute, and to do this Tredgold says:—"To the length of the "hot-house multiplied by half the greatest vertical height add 1½ time "the whole area of glass (all in feet) and also 11 times the number of doors; "the sum will be the number of cubic feet to be heated per minute from the "temperature of the external air to that of the hot-house."

He then says:—"Multiply the cubic feet of air to be heated per minute "by the number of degrees the house is to be warmed, and the result divided "by twice the difference between the temperature of the house and that of "the surface of the pipes, will be the feet super of piping required."

These calculations apply to stoves, forcing-houses, &c. For green-houses, &c., not requiring such powerful heat, a reduction of 10 per cent. may be made in the cubic feet of air to be heated per minute. In the case of a roof having heavy wood framework and rafters, 10 per cent. may be deducted from the net number of cubic feet.

To illustrate these formulæ, let us suppose a lean-to stove-house 40′ 0″ long, 16′ 0″ wide, 15′ 0″ high at back, 5′ 0″ high at front, of which 2′ 6″ is brick-work, and that we wish to maintain a temperature of 70° inside, when the external air is at 20°. We will also suppose the framework of the roof is of iron, or so light that no deduction need be made on account of it.

First, to find the cubic feet of air to be heated per minute, we take the length (40 feet) multiply it by half the greatest vertical height ($7\frac{1}{2}$ feet), add $1\frac{1}{2}$ time the total area of glass (1100) and 11 times the number of doors (2) and we have $(40 \times 7\frac{1}{2}) + (1100 \times 1\frac{1}{2}) + (11 \times 2) = 300 + 1650 + 22 = 1972$. Then we take the cubic feet of air 1972, multiply it by the difference between 70° and 20° and divide the product by twice the difference between 180° and 70°, and we have

$$\frac{1972 \times (70 - 20)}{(180 - 70) \times 2} = \frac{1972 \times 50}{110 \times 2} = \frac{98600}{220} = 448 \text{ square feet of pipe surface.}$$

As each foot run of 4″ pipe contains a little more than one square foot of surface, the above result of 448 represents rather more than the number of linear feet of 4″ pipe which would be required.

For more easily solving the latter part of the problem, after ascertaining the number of cubic feet of air to be heated per minute, Hood gives the figures reproduced in Table XX., showing the number of feet of 4″ pipe which will be sufficient to heat 1000 cubic feet of air per minute to 45° – 90° with the temperature of external air 10° – 50°. This table pre-supposes that the temperature of the pipe is 200°. If it were, the quantities of pipe given would be too much. These, therefore, may be taken as approximately the right figures if a moderate pipe temperature be maintained.

Applying this table to the illustration already given of a stove which requires to be heated to 70° internal temperature with the external air at 20°: we look at the vertical column under the figure 70°, and the horizontal

TABLE XX.—LENGTH OF PIPE REQUIRED TO PRODUCE VARIOUS TEMPERATURES.

Temperature of External Air.	Temperature at which the House is required to be kept.									
	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
°	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
10	126	150	174.	200.	229	259	292	328	367	409
20	91	112	135	160	187	216	247	281	318	358
30	54	75	97	120	145	173	202	234	269	307
32	47	67	89	112	137	164	193	225	259	296
40	18	37	58	80	104	129	157	187	220	255
50	...	...	19	40	62	86	112	140	171	204

column opposite the figure 20° and we find 216 feet of pipe is required per 1000 cubic feet. We multiply this by 1·972 (1,972 being the number of feet to heat per minute), and the result is 426 feet of pipe, which is approximately the same as by the former calculation.

If either of these modes of calculation be adhered to, there will not be much risk of allowing too small a quantity of pipe. Many persons take a higher temperature of external air than 20°, say the mean of the coldest half of the year, which in our climate is about 40°, and reckon upon the necessity for a little forced firing if the temperature fall abnormally low. But this can scarcely be considered a wise policy. For, independently of even a surplus amount of pipe being an advantage, it is only natural that the time when a heating apparatus is generally of most use is during the severest weather.

For rapid calculations, Table XXI., compiled by the author from actual experiments, may be found useful. In order to use it, first find the actual cubic contents in feet of the air in the house. This table pre-supposes that the minimum temperature of the external air remains the same, viz., about 20° Fahr., also that there is a fair amount of wood-work in the structure. An allowance must be made for houses in which there are exceptional facilities for cooling.

TABLE XXI.—LENGTH OF PIPE REQUIRED TO PRODUCE VARIOUS TEMPERATURES.

Description of Buildings.	Temperature of internal air required in degrees Fahr.	Length of 4″ Pipe per 1,000 cubic feet of actual atmospheric contents.	
		Lean-tos, sheltered. Small cooling surface in proportion to cubic contents.	Spans, exposed. Large cooling surface in proportion to cubic contents.
		feet.	feet.
Conservatories and Green-houses ...	Keep out frost.	30 to 35	35 to 40
Vineries, &c.	55 to 65	40 ,, 50	45 ,, 55
Plant Stoves, &c. ...	60 ,, 70	50 ,, 60	55 ,, 65
Forcing Houses, &c.	65 ,, 80	55 ,, 65	60 ,, 70

The foregoing tables, formulæ, &c., must, after all, be considered more or less approximate; and they must be taken in conjunction with several modifying circumstances. For instance, a span-house will, other things being equal, require more pipe than a lean-to; a lean-to facing north will require more than one having a more favourable aspect. A lean-to may, on the other hand, have a more exposed position and possess greater facilities for cooling than a span. A horticultural structure attached to a dwelling-house and protected from a cold aspect, will require less than the same building in the open. The locality in England in which the house is erected must also be considered. More piping is required when it is enclosed in a trench open at the top, or partially covered by an open grating, with the walls of the trench near the pipes, than when the same pipes are exposed above ground. In the former case, it may be calculated that only about 70 per cent. is utilized of the heat given out in the latter case. A universal fault is to specify too small a quantity of pipe.

QUANTITY OF PIPE FOR BOTTOM HEAT.

Pipes used exclusively under borders or in beds need not be reckoned as atmospheric radiating surface at all. In none of the previous calculations are the pipes used as bottom heat taken into account. For the ordinary growth of melons, cucumbers, pines, &c., the author finds from experience that about 9″ of radiating surface for every foot width of bed as shown in Table XXII., will be sufficient.

TABLE XXII.—PIPE REQUIRED FOR BOTTOM HEAT.

Width of Bed.		Rows of Pipes.	Diameter of Pipes.
ft.	ins.		inches.
1	6	2	2
2	0	2	3
3	0	2	4
4	0	3	4
5	0	4	4

POSITION OF PIPES.

A great deal of the success of a heating apparatus depends upon the position of the radiating surface. As concentration and intensity must be avoided, the heating pipes should be distributed as much as practicable. They should also be so placed that they not only promote convective currents, so that none of the air remains unheated, but also, where desirable, that the air, as it enters, should be influenced by the pipes before it reaches the foliage. Thus, pipes are badly placed if exclusively at the back of a lean-to house; for the stratum of air in the immediate vicinity of the pipes is heated, rises, cold air takes its place, and, especially if top ventilators near the ridge be open, a column of air is put in motion near the back, while the air along the roof may remain uninfluenced. Taking the plan of a house, some at least of the pipes should be placed on or near the ground at the point from which the roof springs, that is to say, near the lowest point of the roof. Even if placed exclusively in this position, the column of hot air will rise to the highest part of the house, and in doing so traverse the whole of the roof, an effect which in some houses is exactly what is required. As the ventilating inlets are generally near the front, or lowest part of the roof, this forms an additional reason why the pipes should be placed here. For further security in preventing unheated air from reaching the foliage, it may be advisable, when the front pipes are placed near the ground, to have ventilators immediately behind them in the wall, as explained in the article "Ventilation." Although it is very desirable that pipes should be placed near the lowest part of the roof, for the reasons already given, especially in wide and large section lean-tos, some of the pipes should be placed nearer the back. Other things being equal, it is advisable that the pipes should be on or near the ground, as if placed in a high position, the column of air above the pipes only will be heated and the stratum of air below them liable to remain partially unheated.

No hard and fast lines can be laid down in regard to the position of the pipes, as each case requires to be treated on its own merits. It may be remarked, however, in general terms that:—In a very narrow lean-to vinery or plant-house, the pipes may be exclusively in front (also along the ends, in addition, if required). In a vinery of medium or great width, some of the pipes may be in front, and some at the back of the inside border, next the path. If more piping is required than can conveniently be placed in these positions, it is better, if the house be not too long, to put the surplus piping transversely along the ends, rather than longitudinally, right at the back. In a vinery, care must be taken not to allow the pipes to come too near the stems of vines. In lean-to plant-houses of a moderate or great width, having staging, some of the pipes may be at the front, or front and ends, other pipes, if required, near the path at the front of or underneath back staging. In span-vineries of a fair size, there may be pipes along each side and at the edge of central path on one or both sides; with pipes at the ends in addition, if required. In span plant-houses with side and central stages, pipes may be carried along each side next outer wall, and also, if necessary, underneath and round central stage. The length of a house must determine if the pipes are to be carried longitudinally only or transversely as well. The longer the house in proportion to its width, the less necessity to place pipes at the ends. Again, if the ends of any given house are formed by divisions between that and other houses, instead of ends exposed to the external air, there will not be so much necessity to place pipes at the ends in the former as in the latter case. The glass does not form such a cooling agent in the one instance as in the other. Again, if a span-house have a ridge in the direction of north and south, or if a lean-to house face east or west, there is, of course, the greater necessity that the glass end facing north shall be heated by pipes placed transversely at that end.

There is no limit to the maximum number of rows of pipes which may form one series. It may be necessary to have 2, 3, 4, or even 6, rows of pipes. If 2 or 3 rows, the pipes are usually placed vertically thus:

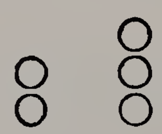


FIG. 93.

If 4 or 6 rows, thus:

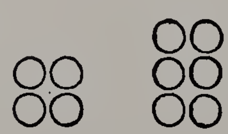


FIG. 94.

with syphons at the ends to unite each series. Instead of coupling each series so that half the number are flow and half return pipes, it is usual to couple a greater number together as flow than as return pipes.

The radiating pipes, when once they rise from the mains, should never be allowed to dip. If there are several door-ways and it would be inconvenient to rise from the main and have a fresh set of pipes in the spaces between the doorways, then the radiating pipes may be placed below the ground line in a trench, uncovered, except by gratings, where the trench crosses the paths. Such a case as this would only be likely to happen in a conservatory or plant-house; it would be scarcely liable to occur in a vinery, especially if there were an inside border. Pipes thus placed, as explained above, lose about thirty per cent. of their heating power. Not only is radiation arrested, but convection is not carried on so efficiently as if the pipes were fully exposed above ground; unless, of course, means were adopted for causing a current of external air to pass over the pipes and enter the house.

The water should be able to rise to the highest point of the radiating pipes as soon and as easily as possible. The water will then have less time and opportunity to cool, there will be the greater difference between the specific gravities of the ascending and descending columns, and circulation will proceed much more effectually.

HEIGHT, ETC., OF COLUMN TO ENSURE CIRCULATION.

To renew the heat in hot-water pipes it is necessary that the water should circulate or move with a certain velocity. This movement, as already explained, is produced by one column of water (that connected with the flow-pipe from the boiler) becoming lighter than another column (that connected with the return pipe to the boiler). The difference in weight between the two columns is the head producing the movement. It is, therefore, very essential that we ascertain the minimum height of column necessary, under vary conditions, to produce the velocity required to renew the heat.

The following set of tables (taken from Box on "Heat"), will enable us to do this. Table XXIII. shows the minimum velocity of current necessary for the renewal of the heat in a 4″ pipe 100 feet long, with different temperatures of pipe, exposed to air at 60°.

From Table XXIV. can be calculated, according to Prony's formula, the head deduced from the velocity.

TABLE XXIII.—VELOCITY OF HOT WATER NECESSARY TO RENEW HEAT.

Temperature of Water		Velocity in feet per second.
As it leaves the Boiler.	As it returns to the Boiler.	
°	°	
210	200	·164
210	190	·0817
210	170	·0367
210	150	·0224
210	130	·0151
210	110	·0107
210	90	·0078

NOTE.—The velocity necessary is simply proportional to the length of pipe.

Table XXV. shows the height of equivalent columns of water at different temperatures, the height at 212° being 12 inches.

To use these tables, find the temperatures of the incoming water, it being understood the out-going water is 210° Fahr., and refer to the third column in Table XXIII., for the necessary velocity. If the length of 4″ pipe be not 100 feet, reduce or increase the velocity in exact proportion to the length of pipe. Then in Table XXIV., take the number in column 2, opposite the given velocity: this multiplied by the length of pipe in inches and divided by the diameter of the pipe in inches (4) will give the required head in inches. Having found the head, we must divide it by the number in the 3rd column opposite the temperature of the in-coming water in

Table XXV., and the result will be the minimum height of a column of water necessary for the renewal of the heat.

Suppose we wish to find the minimum height of column necessary to work a 4″ pipe 500 feet long, the water as it leaves the boiler being 210°, and as it returns to the boiler 190°.

TABLE XXIV.—FRICTION OF WATER IN PIPES.

Velocity in feet per second.	$\frac{H}{L} \times d.$	Velocity in feet per second.	$\frac{H}{L} \times d.$
·01	·000008866	·13	·0001943
·02	·00001870	·14	·0002169
·03	·00002813	·15	·0002394
·04	·00004148	·2	·0003702
·05	·00005437	·25	·0005266
·06	·00006830	·3	·0007080
·07	·00008320	·35	·0009154
·08	·00009920	·4	·001148
·09	·0001161	·45	·001406
·10	·0001341	·5	·001700
·11	·0001532	·55	·00200
·12	·0001732	·6	·00233

By Table XXIII. we find the velocity necessary for a 100-feet pipe is ·0817, this multiplied by 5 (the proportion being 100 to 500 feet) = ·4085, which is a little more than ·4. We may, therefore, take column No. 2 in Table XXIV., as ·00119, which multiplied by the length and divided by the diameter, in inches, gives

$$\frac{\cdot 00119 \times 6000}{4} = 1\cdot 785 \text{ inch. head.}$$

Dividing this head by the figures in the 3rd column of Table XXV. opposite temperature of in-coming water, we have

$$\frac{1{\cdot}785}{{\cdot}092} \quad 19' \; 5'' \text{ height of column required.}$$

If we take the same length of pipe, 500 feet, with the out-going water at 210°, and the in-coming water at 150°, instead of 190°, we then have: Velocity in feet per second for a 100 feet 4″ pipe is ·0224 × 5 (for 500 feet) = ·112. According to Table XXIV., ·0001572 multiplied by length and divided by the diameter, in inches, gives

$$\frac{{\cdot}0001572 \times 6000}{4} = {\cdot}2358 \text{ inch head,}$$

TABLE XXV.—HEIGHT OF A COLUMN OF WATER AT DIFFERENT TEMPERATURES.

Temperature of Water.	Height of Column in inches.	Difference from 212° in inches.	Temperature of Water.	Height of Column in inches.	Difference from 212° in inches.
°			°		
212	12·000	·000	122	11·647	·353
202	11·954	·046	112	11·611	·389
192	11·908	·092	102	11·599	·401
182	11·868	·132	92	11·570	·430
172	11·824	·174	82	11·550	·450
162	11·783	·217	72	11·532	·468
152	11·746	·254	62	11·518	·482
142	11·710	·290	52	11·508	·492
132	11·677	·323	42	11·502	·498

which, divided by ·254, as given in Table XXV., gives ·93 foot column, or under a foot. We thus see that in order to work a length of 500 feet of 4″ pipe, if the water is sent out at 210° and returns at 190°, a minimum total rise of 19′ 5″ is necessary from lowest point of in-coming water to top of pipes; while to work the same length of pipe, if the water is sent out at 210° and returns at only 150°, a rise of barely 1′ 0″ is necessary. Therefore, the greater difference we allow between the temperatures of the in-coming and out-going water, the smaller rise we require from the boiler to top of pipes, and the longer is the length of pipe which can be heated. Again, the higher the vertical column, the longer may be the length of pipe, and with the greater ease does the water circulate. So that combining these two points, we see that the greater the difference between the temperatures of out-going and in-coming water and the higher the column of water, the easier does the apparatus work, and the less necessity is there for forced firing and consequent wasteful expenditure of fuel, and the greater is the quantity of radiating surface which may be employed.

All the previous calculations refer to 4-inch pipe only; 2 and 3-inch pipes require different calculations, but we do not discuss them here, as these pipes are so seldom used as radiating surfaces in horticultural buildings.

Contractions and bends promote friction, and should consequently be avoided whenever possible. If it be practicable, radiating pipes should rise ½ inch in every 9 feet to assist circulation and reduce friction. In a great many instances, however, it is not possible to incline the pipes so much as this; and in some instances they require to be absolutely level. This may be unfortunate, but circulation, although not so brisk, may yet take place sufficiently to renew the heat. Much will, in this case, depend upon the depth the boiler can be placed below its work.

VAPORIZING TROUGHS.

The rate of evaporation of moisture by means of hot-water pipes depends upon the amount of moisture already existing in the atmosphere; the surface exposed; the temperature of the water which is to be evaporated; and whether the air in the vicinity is quiescent or in motion. It is, therefore, obvious that it is not so advantageous to employ a large quantity of water in a tank, as a small quantity in troughs over the pipes. By the latter method evaporation is under better control than by the former. Such troughs may be formed by either vertical flanges cast on the radiating pipes or loose zinc or other troughs having the bottom concave, to fit the pipes. (See "Forcing Beds," and "Hygrometer.")

EXPANSION BOXES AND SUPPLY CISTERNS.

As will be seen by Table XIX., p. 176, 1 gallon of water at about 40° expands, when heated to 212°, to 1·04333 gallons, or about $\frac{1}{23}$rd more. Therefore, supposing a series of pipes be filled with water at 40° and the temperature of the water be raised to 212°, means should be provided for the overflow and retention of $\frac{1}{23}$rd the contents of the pipes. Inasmuch, however, as the water in the pipes never reaches 212°, but can only, in practice, attain 200°; also, as the water before heating is usually more than 40°, and as (especially in extensive arrangements and combinations) the temperature in some of the pipes, notably in the return pipes as they approach the boiler, falls very much below 200°, the volume of water may seldom be calculated to expand more than about $\frac{1}{30}$th of its volume. Provision should be made for this expansion by a cistern marked B on Fig. 92, p. 177. This cistern is usually fixed with its lower part just above the highest point of the pipes, and communicating, by means of a small pipe, with either the bottom of the boiler or a return pipe near the boiler. In this manner circulation is not interfered with, and hot water will not be so liable to rise into the cistern as if it communicated with the water at a higher level. When the apparatus is first filled, it is only necessary to let

TABLE XXVI.—AMOUNT OF WATER CONTAINED IN PIPES.

Size of Pipes.	Gallons in 100 ft. run.
2″	13·58
3″	30·56
4″	54·33

the water rise till it just covers the bottom of the cistern. If the cistern hold $\frac{1}{24}$ to $\frac{1}{30}$ of the contents of the apparatus, the utmost expansion will only cause the water to rise to the top of the cistern. As evaporation takes place, and the water sinks to the bottom of the cistern, fresh water should be supplied. With good stoking a very small daily supply of water is required for this purpose. Table XXVI., p. 192, showing the amount of water contained in pipes of different diameters, may be useful.

Although, especially in large establishments, it is useful to have a water supply near the expansion cistern, it is seldom advisable or necessary to have a self-feeding ball-valve in the cistern itself; as the ball-valve is very apt to get out of order, especially if hot water happen to rise into the cistern, and the supply of water required be comparatively trifling.

Although the supply and expansion cistern should be fixed above the highest point of the pipes, it is not advisable to allow it to be fixed much higher than is absolutely necessary, or the pressure resulting from the head of water will be unnecessarily increased. Each foot head of water produces a pressure of ·433 ℔. per square inch. In small arrangements of piping, or where the boiler is very powerful in proportion to the work it has to do, there is the danger of the water boiling into the cistern, evaporating and wasting too rapidly. This is prevented by proper stoking.

The expansion cistern and pipe leading to it should be out of the influence of frost; and for greater security, if the cistern be made slightly wider and longer at the top than the bottom, frost will not be so liable to fracture it.

A draw-off tap should be inserted in the lowest part of the boiler; or, if more convenient, in the pipe leading into the boiler from the supply cistern, if this pipe enter the boiler at the lowest part. (See Fig. 92.)

AIR PIPES.

In order that the water may circulate properly, it is necessary that the pipes and boiler should be completely filled with water. This point is of extreme importance in hot-water heating. If any air be allowed to remain in the pipes, it forms as much an obstruction to circulation as a solid substance. Therefore, it is necessary that there should be outlets at the highest points of the pipes, for the escape of air or any steam which may be generated. If, in the same hot-water apparatus, there be several series of pipes, an air outlet should be provided at the highest point of each series. Or, in one series, if there happen to be a rise in more than one place, with a depression between, an air outlet should be provided at the highest point of each rise. For air is 827 times lighter than water; consequently the former would not be liable to descend in order to pass an obstruction caused by the latter. These air outlets are usually in the form of small metal pipes inserted where necessary; or where this is inconvenient, small taps may be inserted in the top of the pipes. In the latter case, the taps can, of course, only act when they are turned on, and therefore require attention at least twice a day. In the former case, when air-pipes are used, they are self-acting, should be carried up some 8 or 9 feet above the top of the apparatus, and have their ends turned over thus ʃ (see E, Fig. 92) in order that nothing may enter them. These ends are sometimes carried outside the house and turned into the gutter or spout. If this be done, great care should be taken that the air-pipes are carried to a good vertical height, say 8 or 9 feet above the apparatus; or the water may be forced up the pipe, remain in the part exposed to the external air, and freeze. In cases where it is impossible to have long lengths of air-pipe; or where there is a probability of water in the air-pipes freezing, short lengths of pipe and taps, or taps only, may be used; but whenever practicable, self-acting air-pipes are preferable. The diameter of air-pipes may be very small, for the velocity of fluids, under equal pressures, is in inverse proportion to their specific gravities; therefore, air would escape from a pipe 827 times faster than water.

MAINS.

It is frequently inconvenient and impossible for the radiating pipes to be directly attached to the boiler. Therefore, it is customary to connect these pipes with the boiler by two main or supply pipes, one fixed to the highest part of the boiler for the out-going, ascending or "flow" water, the other fixed to the lowest part of the boiler for the in-coming, descending or "return" water. It is, of course, essential that heat should not radiate from these pipes, or power would be lost in transmission between the boiler and the radiating surface proper. To obviate this difficulty, the main pipes when they are underground, are usually enclosed in a brick trench, and either covered with felt or some other bad conductor, or, what is better, supported in a jacket of quiescent air, which is one of the worst conductors of heat. Brick is also a bad conductor, so that if the main pipes are simply supported in a hollow, covered, brick trench between the boiler and the place where they are joined to the radiating pipes, such mains will be more likely to retain their heat than in any other way. When the hot-water first begins to flow along such air-lagged pipes, the heat radiates from the surface, the air-jacket and surrounding bricks are warmed, and when the temperature of pipes, air, and bricks is identical, further radiation almost stops. Main pipes which have to pass through any open space (such as a cellar, &c. where brick trenches are impossible), must, of course, be lagged with felt, silicate cotton, or other similar bad conductor of heat.

The same remarks made in regard to the friction and necessity for a continual rise in radiating pipes, will apply to main pipes, with the exception that, as the latter are usually smaller than the former, there is increased friction. To equalize the friction, vertical main pipes need not be so large as those which approach the horizontal. The latter should certainly, if practicable, have a rise of at least $\frac{1}{2}$ inch in every 9 feet.

Main pipes are usually either 2″ or 3″ in diameter, according to the distance and vertical rise between the boiler and radiating pipes, and the

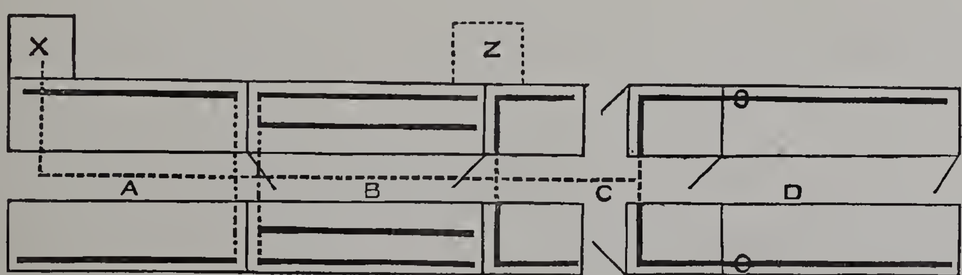


FIG. 95.—Ground plan of arrangement of hot-water mains and pipes.
Scale, $\frac{1}{16}$ inch = 1 foot.

amount of latter to feed. If, however, the distance be very great and the radiating surface to feed large, it may become necessary to have 4 inch (or even larger) mains, and to be very careful in having a high vertical column to overcome the friction.

Besides being used as absolute connection between boiler and heating pipes, mains are chiefly used for the purpose of obviating the necessity for the dip of pipes under door-ways, and of enabling consecutive houses, as well as different features of one house, to be heated separately and independently. For instance, Fig. 95, shows an arrangement of mains in a range of four span-houses. A, we will suppose, is a plant stove; B, a cucumber and melon-house; C, a green-house; and D, an orchard-house; all heated. The boiler is at X. There is a door at each end, and at each division; and in addition, two transverse doors in greenhouse C. Dotted lines inside the range are mains; thick lines radiating pipes. It will be seen that the mains come direct from the boiler, and proceed straight up the centre of path. Branches from the mains are taken to supply the heating pipes under the staging in house A. Further branches are then taken to supply the bottom heat as well as atmospheric heat in house B. In C, branches are provided to supply the pipes on each side of transverse doorways, so that no dip under them is necessary. We will leave D out of the question at present, as it is heated in a manner of which we will speak later on. This figure does not necessarily show a model arrangement of mains, but merely illustrates the various ways in which they may be disposed.

It will be seen by the above adaptation of mains, that C, or any part of it, can be heated, whilst the heat of A and B are absolutely cut off; that B can be heated whilst A and C are cut off; that either top or bottom heat in B can be cut off without interfering with the other; in fact, that either house or part of a house, or any combination of A B and C, can be heated quite independently of the remainder. The boiler and its position will be discussed later on, but in so far as the position of the boiler relates to the mains, it may be mentioned here, that in planning a range of several houses, it is frequently found advisable to place the boiler near the centre of the range, as at Z, in Fig. 95. By this arrangement, mains may be taken from each side the boiler, and the water circulated in both directions instead of in one only. Provided the mains are well protected from radiation, there is not so much necessity to have the boiler nearest to those houses which require the greatest amount of heat. This, as will be seen in "Radiating

Surface," p. 180, depends, other things being equal, upon the amount of radiating surface.

When a number of houses have to be heated from one boiler, it is often advisable to reduce the friction of the circulation by increasing the number as well as the size of the mains connected with the boiler.

Mains (as in fact all the parts of a hot-water apparatus) should be easily accessible, and the trenches containing them should be capable of being readily cleared of any accumulation of dirt, &c.

VALVES.

Closely associated with mains for the supply of heat, are valves for the moderation and stoppage of heat. We have seen (Table XXIII.) that, to renew the heat in hot-water pipes, it is necessary for the water to move with a certain volocity. Now, if we allow the fire to diminish, the nearer will the temperature of the out-going water approximate to that of the in-coming water, and the less will be the velocity; until a limit is reached when there is not sufficient velocity to renew the heat at all. Therefore, in a small apparatus, or one in which a single house or set of pipes requires to be heated, we may easily moderate or stop the heat at will, by increasing or diminishing the intensity of the fire.

In most cases, however, there is more than one compartment or set of pipes to be driven from one source of heat. The necessity, therefore, arises for having the power to check or altogether stop the circulation in one or more sets of pipes, leaving the circulation altogether unimpeded in the remaining pipes. To effect this, check or throttle valves are used. These valves are generally similar in construction to Fig. 86, p. 142, and like throttle-ventilating valves, are in equilibrium, so that the movement of water has no tendency either to close or open the valves. When fully open, the disc of a throttle valve is only opposed edgewise to the circulation of the water. When closed, the circulation is completely stopped. Valves, however, which, when open, present no obstruction whatever to the circulation of the water, are better than any others. When valves are required merely to impede the circulation, it is frequently considered unnecessary to have a valve on the return pipe as well as on the flow-pipe.

If, however, the boiler be very powerful, or it be driven hard, and the pipes lend themselves to the purpose, a valve on the flow-pipe only, may frequently have the effect of diverting rather than impeding the circulation. It may be taken as a general rule that valves should always be fixed on both flow and return pipes. In Fig. 95, valves may be placed on any or all of the rising mains which branch out of the central longitudinal main.

The usual throttle-valve impedes circulation, but does not resist the pressure of water. It is frequently necessary to have high pressure valves, as for instance, between a boiler in work and one in reserve; between boilers coupled, both of which are at work; or at certain points in large complicated arrangements of pipes; so that in a case of a break-down or an accident to part of the apparatus, the water may be completely drawn from such part, whilst the remainder may be at full work. When high pressure valves are employed, they should not be of the usual "screw-down" type, in which there is a circuitous passage, but should have a full, straight, clear, water-way when open. The following valve, Fig. 96, fulfils these conditions.

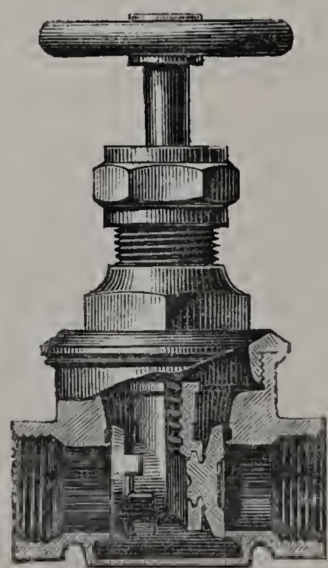


FIG. 96.—Section of high pressure straight full-way valve. (Dennis & Co.'s patent.)

In the act of closing this valve, two discs are pressed by a mechanical screw-motion against the seats and resist any pressure. When the valve is opened, the discs recede slightly from their seats and are raised completely out of the water-way. The engraving shows a valve with screwed ends, but the principle is equally applied to valves with spigot socket or flange ends.

Fig. 97 shows an ordinary throttle valve. It is sometimes recommended to have a high pressure valve on a flow, and a throttle valve on a return pipe, but no advantage can be gained by such a combination. If high pressure valves are used, they should, of course, be fixed on both flow and return-pipes.

There is one application of valves and pipes to which attention must be directed. On referring to Fig. 95, p. 195, it will be noticed that the

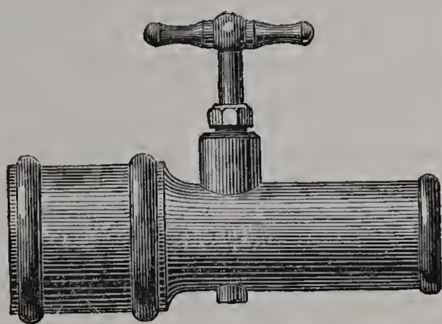


FIG. 97.—Throttle valve.

longitudinal mains stop short in compartment C and do not run into house D, the radiating pipes on each side of one end of C being continued straight through into D. At the points where the pipes enter D, H pieces and valves are fixed, as shown by Fig. 98.

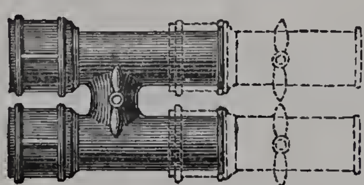


FIG. 98.—H pipe and valves.

When it is required to heat D, the valve in the centre of the H piece is closed, and the other two valves opened. When it is required to shut off heat from house D, the central valve is opened and the other two closed. The obvious disadvantage of this system is, that D can never be heated unless C is heated also.

JOINTS.

The most usual pipes for horticultural hot-water heating are those having spigot and socket ends. Pipes with flange ends are sometimes employed, but very seldom. In the latter case, vulcanized india-rubber washers make water-tight joints between the flanges, which are bolted together. With the spigot and socket ends, several joints are applicable. One is the rust joint; that in which the space between the socket and spigot is caulked with rope, then hermetically sealed with a rust mixture of damp iron-filings and sal-ammoniac. It is almost impossible to disconnect this joint when it is once made, without breaking the pipes. Another joint is made by caulking the pipes with rope and a mixture of red and white lead. Another, by caulking with rope and Portland cement. The easiest joint, however, to make, the one which will be most liable to resist leakage, and that most readily unmade, is formed by vulcanized india-rubber rings of a round section. In making this joint, the ring simply requires to be placed on the extreme end of the spigot, which must then be pushed home in the socket or collar. The ring then occupies a position about midway between the end of the socket and end of the spigot, and is rolled into a flat, oval section. (See Fig. 99.) After the water is made to circulate in the pipes

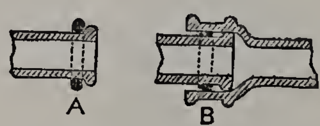


FIG. 99.—Section of india-rubber ring joint.
A Ring before, *B* Ring after, insertion between socket and spigot.

for a short time, the heat causes the external surface of the rings to unite to the pipes, and the joints will, if not interfered with, remain sound for many years. A few minutes will suffice either to repair such a joint by inserting a new ring, or unmake a joint for the purpose of using the pipes elsewhere. India-rubber rings should, of course, not be used for the joints nearest to the boiler. An apparatus having india-rubber ring-joints may be started immediately the rings are inserted, but the rust and cement joints should be allowed to harden and dry, before the pipes are filled with water. India-rubber rings allow the pipes to expand or contract, so that there is not so much liability of that leakage to which other joints are exposed.

As previously mentioned (see "Iron *v.* Wood-Houses," p. 51), the linear expansion of cast-iron by heat from 32° to 212° is 1 part in 889, or about 1·35-inch in 100 feet. It is, therefore, necessary that the pipes, especially with rigid joints, should be fixed in such a manner that linear expansion can take place or the joints will be apt to leak. The expansion in the flow will not be the same as that in the return pipe, if the temperature differ in the two pipes.

Some hot-water engineers have their own form of joints, necessitating the pipes which are used having some special pattern of end. The possible difficulty of subsequently obtaining tbe same pattern of pipes for alterations or additions, and the very problematical advantages which any of these joints have over socket and spigot pipes with india-rubber rings, render the latter system of joints practically master of the situation.

BOILERS.

An almost endless variety of hot-water boilers has been brought out. A description of all, or even of part of them, would be much too lengthy for these pages; we therefore propose to give a short analysis of the principles involved in, and a list of some of the points of boilers generally.

Primarily, the power of a boiler depends upon the area of heating surface, but when flame and hot gases come in contact with a surface not so hot as themselves, the amount of heat given out depends upon the position of the receiving surface. This latter is only considered fully effective when it is flat and horizontal, and the fire is beneath it. Vertical surfaces above the flame are calculated at 50 per cent. of efficiency, and horizontal surfaces beneath the flame are not reckoned at all. For instance, suppose we have a rectangular boiler A B C D, Fig. 100, with the fire beneath it. The whole of the surface A is effective because the flame, &c., rises, impinges directly upon the surface, the water in the lower part of the boiler is heated, rises, and gives place to colder water. There is not the inclination for hot gases, &c., to impinge upon C, and if they did, the upper surface only of the water would be warmed and convective currents would not be so liable to take place. Moreover, fine ashes and soot would be liable to rest upon C and further impede the conduction of heat to the mass of water. A being reckoned as 1, B and D as $\frac{1}{2}$ each, and C as 0, the total effective heating surface of such a boiler would be 2 as against 4, or half the total area. The converse of this would take place if the figure A B C D represented an internal furnace with water space all round. C would then be reckoned as 1; B and D as $\frac{1}{2}$ each; and A as 0. The result, $\frac{1}{2}$ the total area of effective heating surface, would remain the same as before.

Besides the primary surface, or that upon which the flame impinges, a boiler frequently contains surfaces which are out of reach of the actual flame, but are influenced by the heated products of combustion on their passage to the chimney. The effective heating power of such secondary flue or tube surfaces is usually calculated at about one-third of their area (Hood) or $1\frac{1}{4}$ of their diameter (Molesworth).

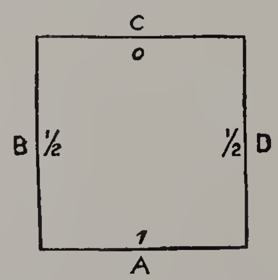


FIG. 100.—Vertical section of boiler showing effective heating surface.

Every square foot of direct effective heating surface in a boiler may be estimated to heat 40 to 50 feet of 4-inch; 55 to 66 feet of 3-inch; or 80 to 100 feet of 2-inch pipe. Discretion must be used in deducing the size of a boiler from the above calculations. For the loss of heat by radiation is much greater, in proportion, in a small boiler than a large one; added to which, in the former, the air generally passes into the chimney at a much higher temperature than in the latter.

Again, much depends upon the stoking. With forced firing, and a double consumption of fuel, more heat can be obtained from a boiler than under normal conditions. But such a course does not give proportional efficiency, for a double consumption of fuel means much less than double heating power. All the makers give the length of pipe which their respective boilers are calculated to heat. The most advantageous course to pursue, however, in regard to economy of fuel, is to have a boiler which will heat 50 per cent. more pipe than that required; in other words not more than $\frac{2}{3}$ of the maximum amount of pipe, which a boiler is calculated to heat, should be attached to it. Some authorities attempt to deduce the amount of heating surface required, direct from the house to heat. For instance, one rule given is this: "Take the cubic contents of "the house to heat, and for half-hardy plants give to every 100 feet, 10 "square inches of boiler surface, and 1 square inch of fire-grate; for tropical "plants double these proportions; and for forcing-houses take intermediate "proportions, according to the temperature required." As we have seen that the temperature obtained in a house, depends, not so much upon the boiler-power, as upon area of radiating surface in that house, it is obvious that the only proper course to pursue is, first, to determine the amount of pipe necessary, and then, from this, to calculate the size and power of boiler required.

There is no doubt, that in the selection of a boiler, that one is the most economical, which, other things being equal, presents the greatest amount of area to the direct action of the fire. Such a boiler would be better than one presenting a small area to direct fire-action, and chiefly depending for its power on auxiliary or secondary heating surface. The fundamental test of a boiler and its adjuncts, is not so much whether it affords the maximum amount of heat, as how much heat it expends on the external atmosphere, instead of on the air of the building to be warmed. That is to say, whether it abstracts the greatest amount of heat from the fuel and gives it out again at the radiating surface. So much depends upon the boiler setting and furnace, that these must be taken into due consideration in determining the choice of a boiler.

Boilers are made of cast and wrought iron. Cast iron is not so favourable to corrosion and incrustation as wrought iron. The former is not so suited, of course, to resist pressure as the latter; but the necessity for resisting pressure is not so paramount, when we consider that the only pressure which ought to exist is that due to the head of water. (See "Position of Boiler.") With ordinary fair stoking, no steam whatever should be generated. Still, all boilers, whether of wrought-iron or cast, should be tested, before being used, to a pressure of not less than 40 lbs. to the square inch.

Boilers are constructed of all descriptions of shapes, but they are usually divided into two classes :—Saddle boilers and tubular boilers. The former may be described as presenting more or less a flat surface, the latter a series of tubes, to the action of the fire. Saddle boilers assume various shapes in consequence of manufacturers subdividing and multiplying flues, in order that, independently of the surface exposed to the direct action of the fire, as large a secondary surface as possible may be utilized for the purpose of extracting the maximum amount of heat before the chimney is reached. Corrugations are made on the surfaces of saddle boilers, in order that the hot gases and flame may not be so liable to glide past without impact. Sometimes, for extensive work, the saddle type is extended until it reaches the ordinary "Cornish" boiler. Saddles of all shapes are usually made of wrought-iron ; some, however, having several longitudinal internal flues, are built up of cast-iron.

There is not so much scope for diversity in the form of tubular boilers ; but manufacturers are not slow to adopt different shapes when they consider that advantages may be gained. Sometimes vertical tubes are inserted into a top and bottom ring, the former rather smaller than the latter, so that a conical shape is obtained ; a communication with the bottom ring forming the return in-let, and a communication with the upper ring, the flow out-let. Sometimes such boilers are constructed without a joint at the junction of the tubes with the rings. Again, the tubes are sometimes placed horizontally, one above the other, and each one shorter than the one beneath it, so that a conical shape is obtained. There are very many variations and combinations, but all boilers may be divided into four groups, of which Figs. 101, 102, 103, and 104, may be taken as excellent representatives.

Fig. 101 shows the ordinary wrought-iron saddle boiler. In setting such a boiler, fire-brick longitudinal mid-feathers are usually placed at each side, so that after the hot gases have impinged upon the crown of the boiler they may pass outside from back to front under the mid-feather; then from front to back on the top of the boiler; then up the chimney.

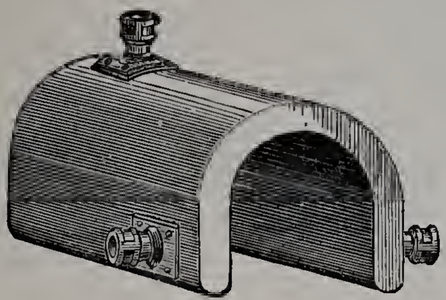


FIG. 101.—Saddle boiler.

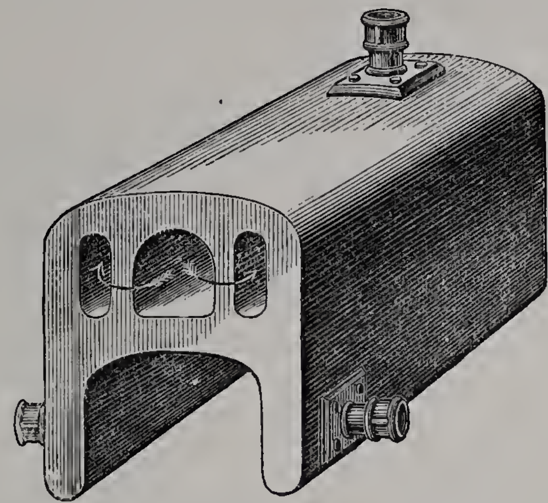


FIG. 102.—Hartley & Sugden's "Gold Medal" boiler.

The furnace is underneath the boiler, the fuel being usually fed in front. Within the last few years, however, an invention has been brought out for the top feeding of saddle boilers by the insertion of a tube in the crown.

Fig. 102 shows the saddle type in a more improved form. Besides the surface against which the flame impinges and the exterior surface (as in an ordinary saddle) there are, in this boiler, three additional flues. After quitting the furnace and passing to the back of the boiler, the products of combustion pass to the front of the boiler in one stream through the central flue and return to the back in two streams by the side flues, as shown by the arrows.

Fig. 103 shows an upright tubular boiler. The construction is as follows:—The boiler itself, which is divided into two halves, consists of three hollow chambers, viz., bottom, diaphragm, and top chambers. These are connected by double rows of vertical tubes. The middle or diaphragm chamber is adjusted by plates to prevent the escape of unconsumed gases, and is intended to act not only as a fuel-economizer, but as a partial smoke consumer. By dividing the boiler into two halves, each half can be passed through an opening 18 inches wide. Also, in case of an accident happening to one-half, it can be removed, and the other half left working. It will also be noticed that water fire-bars are attached to the boiler.

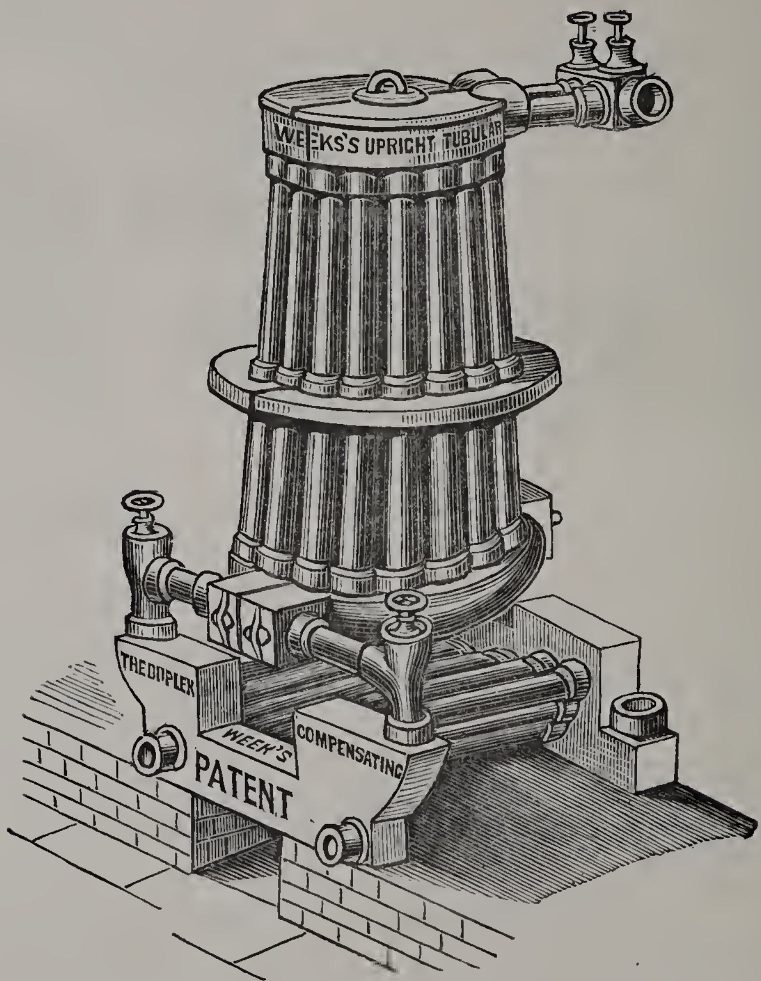


FIG. 103.—Weeks' patent duplex upright tubular boiler.

Fig. 104 shows a horizontal tubular boiler. The construction is as follows:—The boiler is composed of cast-iron rings, each ring comprises four tubes in the same plane. The marks on the corner posts show the junction of these rings, so that in the figure there are four rings. Consequently there are no joints at the junction of the tubes with the corner posts. Corner plates and a bolt through each corner-post serve to hold the rings in their places. The tubes are made horizontal and their combined shape conical, in order that the flame and hot gases may impinge on the heating surface at right-angles instead of gliding past. The corner posts being hollow, serve as conduits for the circulation of the water. Being

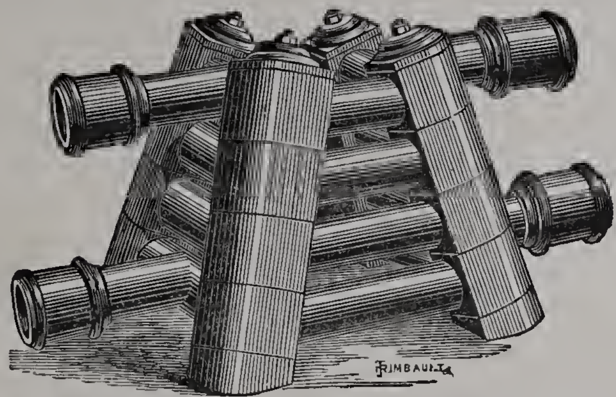


FIG. 104.—Dennis' patent "A 1" horizontal tubular boiler.

built up of segments, such a boiler, in case of accident, can very easily and rapidly be taken to pieces, and fresh rings inserted. Although the figure does not show it, this boiler can be provided with water fire-bars. A boiler having horizontal tubes, necessitates, other things being equal, a much shallower stoke-hole than a boiler having vertical tubes.

There can be no doubt that a tubular boiler, size for size, contains a much larger area of heating surface than a boiler of the saddle type, consequently the former may *per se* be regarded as more efficient than the latter. This is especially the case when we consider that hot-water boilers gain nothing by containing a large quantity of water in proportion to their heating surface. On the contrary, a boiler may gain vastly in efficiency by containing the smallest amount of water with the largest area of heating surface. They should, of course, be always full of water, consequently there ought to be no liability of sustaining damage by total evaporation of water. No steam is supposed to be generated, or if it be, no pressure should exist beyond the head of water, so that an explosion or fracture by increased pressure ought never to be possible.

Some of the conditions which determine the choice of a boiler may be roughly summed up as follows :—

Amount of effective primary heating surface in a given space.

Amount of effective secondary heating surface in a given space.

The adaptability of the boiler for being set at such a level that no inconvenience may result from insufficient drainage.

The position it will occupy.

Its adaptability for enabling the maximum amount of heat to be extracted before the products of combustion are discharged into the chimney.

Its adaptability for being easily taken to pieces, repaired, and renewed.

Its adaptability for the fuel which is most easily obtained in the locality, and for the work which it is required to perform.

Minimum obstruction to upward passage of water, as well as to the flow and return of water.

Flow-pipe or pipes should be at the highest part of boiler, return-pipe or pipes at the lowest.

These points are placed before the prospective purchaser of a boiler, but his particular case can only be treated on its own merits ; therefore, it impossible, without knowing all the conditions, to recommend any particular boiler in preference to another. The opinion, however, may be safely advanced, that other things being equal, cast-iron is better than wrought ; tubular boilers are better than saddle ; and boilers with horizontal tubes better than those with vertical.

If clean rain-water be used in hot-water boilers, deposit or incrustation will not be so liable to occur as if hard water be used. Water always in circulation, and passing in and out of the boiler, tends to keep it free from deposit. Besides this, hot-water boilers are not so liable to incrustation as boilers in which the water is used exclusively for the generation of steam.

For the sake of economy of fuel and to decrease the attention required for stoking, owners of small conservatories or green-houses attached to a dwelling, often desire to work the heating pipes from the kitchen-boiler.

If the green-house and kitchen floors be on the same level, such a course is scarcely ever advisable; for in all probability the boiler could not be connected with the radiating pipes unless the supply-pipes dipped below the floor. Even if no such dipping were necessary, it might not be convenient or possible to fix the radiating pipes higher than the boiler. Added to this, if a bath on an upper floor be heated from the same boiler, or if, in connection with the boiler, there be a hot-water supply cistern on a higher level than the green-house, for culinary and domestic purposes, the green-house pipes will frequently contain only cool water, as the hot-water will naturally flow to the highest points. Again, a kitchen grate has usually a small fuel capacity, and is not constructed for maintaining combustion for a long time without attention; consequently, during the night, when the green-house heating would be most necessary, the fire, although banked up, might be liable to go out. It will generally be found more economical, when possible, to heat a green-house from a separate special boiler.

In large and complicated arrangements, it is very usual to heat the whole of the pipes from one boiler. This may be very economical and desirable; but if a break-down in this one boiler take place, during, perhaps, a heavy frost, great damage may occur. In such a case, it will be found desirable to work, either with two boilers, coupled in such a way that if one of them break down, the remaining one can be turned on to the whole of the pipes; or to work with one boiler, but have a similar one in reserve, coupled to it.

In very long ranges, or where the houses are straggling and not compactly arranged, it may become advisable to have more than one central source of heat, and establish boilers at different points. Economy and efficiency may thus be increased by obviating the necessity for numerous long lengths of mains.

INDEPENDENT BOILERS.

Although the most advantageous material for setting a boiler is that which has low-heat transmitting power (such as brick-work), it is frequently desirable that a boiler should be portable. In such a case, to obtain an independent setting, it is usually necessary to employ iron, which is a good conductor of heat, and sacrifice a little power to portability. It is of not so much importance if very small portable boilers are exposed without lagging of any kind; but larger portable boilers should be provided with some means for arresting the radiation of heat into the stoke-hole.

The ordinary independent boiler is of the upright conical form, either rectangular or circular in plan: a form which is practically nothing more than a modified saddle boiler.

Fig. 105 shows a rectangular conical independent boiler.

This boiler has sliding doors in front, and a throttle damper at the back, for the entrance and exit of air. The dotted line shows a conical "feeder," by which the boiler may hold in reserve an additional supply of fuel.

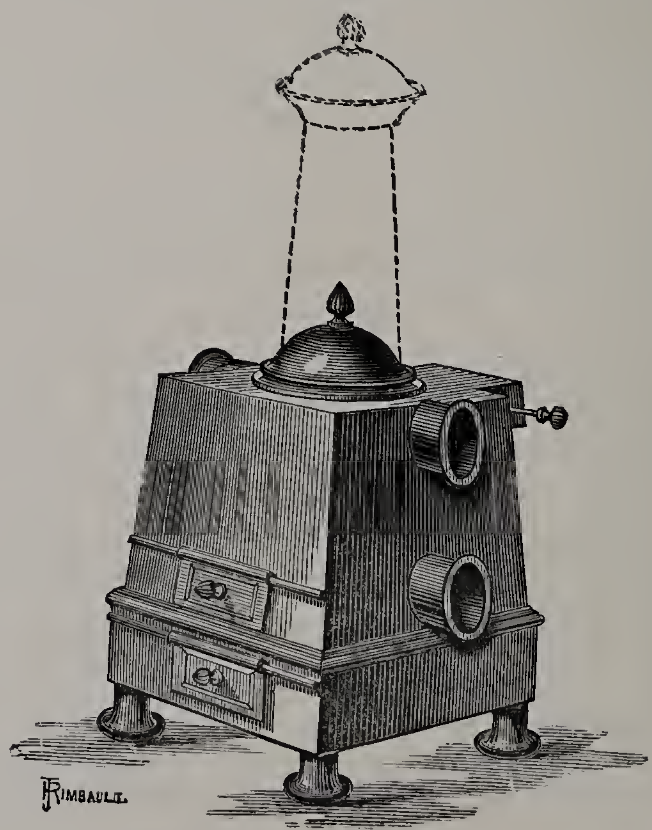


FIG. 105.—Independent conical boiler.

For a small apparatus in which not more than about 100 feet of 4-inch pipe requires to be heated, and stoke-hole space is very limited, such a boiler as this is very useful.

Figs. 106 and 107 show independent boilers of a larger type.

These boilers have a patent air jacket of rather ingenious construction. It will be seen that they have around them an iron casing; surrounding this is another iron casing. Perforations in the bottom of the outer casing admit air to the space between the two casings. Perforations in the inner casing admit part of this air underneath the fire-bars, the remainder of the air rises between the two casings, and is fed into the top of the furnace. The supply of air being limited under the bars, there is a tendency for carbonic oxide to form, but on receiving the additional supply of air from the top, this carbonic oxide is converted into carbonic acid, and therefore loss of heat from this source is obviated (see p. 213).

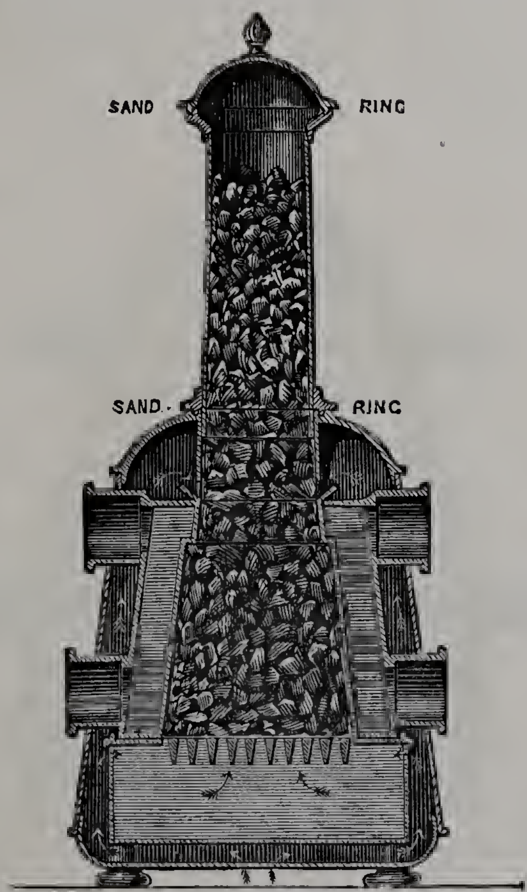


FIG. 106.—Independent hot-air cased boiler. (Dennis & Co.'s patent, A 2 C.)

Again, the air which is constantly passing between the two casings, takes, by convection, the heat, which would otherwise escape by radiation from the outer casing, back into the furnace. The apparatus is thus provided with a "lagging" and a "feed-air heater" at the same time. As, moreover, oxygen is supplied to the top of furnace as well as the bottom, the fuel may be fed in a greater thickness, and will therefore last longer without attention than if the air were admitted exclusively under the fire-bars. In locomotive and other boilers where there is every means for admitting air to the fire-bars, the thickness of fuel in the furnace frequently necessitates admission of air above the fire, or the loss of heat from the formation of carbonic oxide would be enormous.

An independent boiler should never be fixed inside the house which it is required to heat. It is false economy to do this in order to attempt to utilize the heat which may radiate from the boiler itself; for great damage may occur if the products of combustion are liable to mingle with the atmosphere of the house.

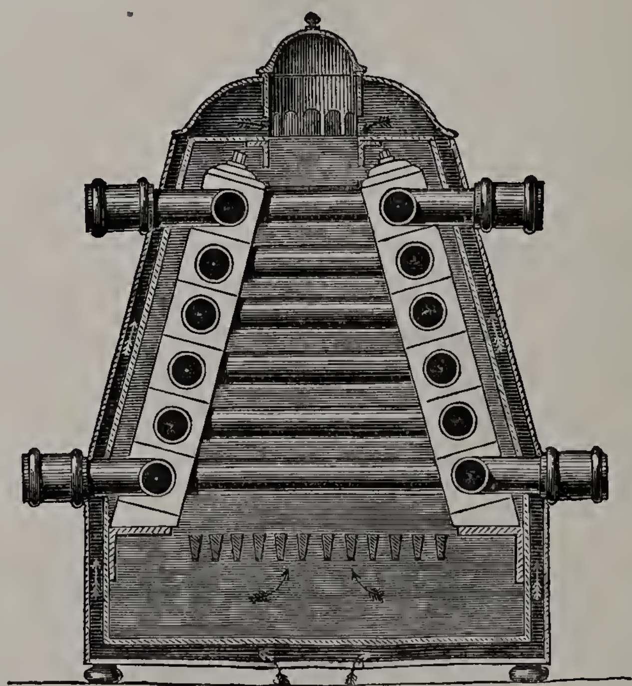


FIG. 107.—Independent hot-air cased tubular boiler. (Dennis & Co.'s patent, A 1 C.)

FURNACES AND BOILER SETTINGS.

The success or failure of a boiler depends to a great extent on the manner in which it is set. Although other conditions are necessary, careful or careless setting will very frequently make or mar a heating apparatus.

As will be seen in the section "Fuel," p. 220, the air has to supply the oxygen required for combustion; therefore the first note to make is the amount of air required for different combustibles.

Supposing the whole of the oxygen to be consumed, the minimum quantity of air necessary for the combustion of one pound of carbon, is 158 cubic feet, and for one pound of hydrogen, 473 cubic feet of air; the temperature of the air in both cases being 62° Fahr. But, by the analysis of air which leaves chimneys, we find that in a usual way, it only parts with about half its oxygen, consequently, in practice, double the above quantities of air would be required.

If the quantity of oxygen supplied during combustion be sufficient, two atoms of oxygen combine with one of carbon and carbonic acid is formed. If the quantity be insufficient and one atom of carbon be able to combine with only one of oxygen, then carbonic oxide is formed. Or if there be less

TABLE XXVII.—AIR REQUIRED FOR THE COMBUSTION OF VARIOUS FUELS.

Fuel.	Cubic feet of air at 62° required per pound of fuel.
Coal...	294
Coke	269
Wood, dry	161
Wood, ordinary state ...	129
Charcoal...	294
Peat, dry...	202
Peat, ordinary state ...	163

than 2 to 1 and more than 1 to 1, then part of the oxygen in the air is taken to form carbonic acid and the remainder to form carbonic oxide. Now whenever carbonic oxide is formed, less than half the heat is yielded than when carbonic acid is formed. For Favre and Silbermann's experiments show that a pound of carbon burning to carbonic oxide yields only 4,453 units of heat; whilst Dulong's experiments show that in burning the same amount of carbon to carbonic acid, 12,906 units of heat are yielded. (For the value of a unit of heat see "Fuel," p. 221.) By the analysis of fuels on p. 221, we find that coal contains an average of ·804 carbon and (after allowing for the oxygen present in it) ·04206 available hydrogen in excess.

To find therefore the cubic feet of air required for one pound of coal we take

$$(\cdot 804 \times 158) + (\cdot 04206 \times 473) \times 2 = 294 \text{ cubic feet air at } 62^\circ.$$

In this manner, Table XXVII., on p. 213 is constructed:—

Taking the temperature of the air and products of combustion issuing from the chimney of a steam engine at 550° Fahr., Mr. Box estimates the following to be the volumes with different fuels:—

TABLE XXVIII.—VOLUMES OF AIR, ETC., EMITTED FROM THE CHIMNEY AFTER BURNING VARIOUS FUELS.

Fuel.	Cubic feet at 550° Fahr. per pound of fuel consumed.
Coal...	608
Coke	538
Wood, dry	342
Wood, ordinary state ...	282
Charcoal	588
Peat, dry...	427
Peat, ordinary state ...	352

For the much slower combustion in hot-water boilers, and lower temperature at which the products of combustion leave (or ought to leave) the furnace, the preceding figures may be somewhat modified, as air expands about double its volume between 62° and 500°.

We therefore see that much depends upon the admission of air to a furnace. With too little air, carbonic oxide is apt to be formed ; with too much, the velocity of draught is apt to be increased, a roaring fire (that delight of many an unintelligent stoker) produced, and in either case, loss of heat engendered. The air is admitted to a furnace by the grate and also by the doors, and it finds its exit by the chimney. The proper mode of checking the speed of combustion is by adjusting the size of the outlet. Therefore, while the fire-bars remain permanent, the size of outlet into chimney is usually adjusted by a damper, the proper manipulation of which is of extreme importance, and is one of the chief tests of an efficient stoker.

TABLE XXIX.—DIMENSIONS OF FIRE-BARS.

$\frac{7}{8}''$ thick at top.
$\frac{3}{8}''$ " bottom.
$\frac{3}{8}$ to $\frac{1}{2}''$ air spaces between.

Length.	Depth.	Weight.	Weight per square foot.	Length.	Depth.	Weight.	Weight per square feet.
ft. in.	ins.	lbs.	lbs.	ft. in.	ins.	lbs.	lbs.
1 0	$2\frac{1}{2}$	6·4	64	2 9	$4\frac{1}{4}$	20·75	76
1 3	$2\frac{3}{4}$	8·1	64	3 0	$4\frac{1}{2}$	23·75	79
1 6	3	9·5	64	3 3	$4\frac{3}{4}$	29·	89
1 9	$3\frac{1}{4}$	11·4	65	3 6	5	32·	91
2 0	$3\frac{1}{2}$	13·0	65	3 9	$5\frac{1}{4}$	35·	93
2 3	$3\frac{3}{4}$	15·5	69	4 0	$5\frac{1}{2}$	39·	98
2 6	4	18·0	72	4 3	$5\frac{3}{4}$	42·	100

Although air can be admitted above as well as below the fire-bars, in usual cases it is advisable to employ the latter only, when more perfect combustion takes place. One furnace door is generally provided on a level with the bars, for feeding or stoking, and another door below for raking out the ashes. Both of these, but especially the former, should fit accurately;

the former in order that air may not enter the furnace between the fire and the boiler and cool it; the latter in order that admission of air to fire-bars may be regulated as required. Thin fire-bars will last longer than thick, as the passage of air past them keeps the former cooler than the latter. Experience, and the investigations of Hood, Box and others, show that approximately the best dimensions for fire-bars are those given in Table XXIX. The thickness and air spaces may be considered constant for all sizes, but the depth in the centre should vary with the length, as shown in the table. It is never advisable to have a greater length of fire-bar than about 3 feet.

The rate of combustion of fuel depends upon the amount of air admitted to the furnace, and, therefore, upon the area of grate-bar surface, not upon the total size of furnace; although with a given area of bars (the velocity of influx of air remaining the same), the larger the furnace, within fair limits, the more fuel it will hold, and the longer it will burn without attention. An important point in horticulture heating.

TABLE XXX.—RELATION BETWEEN AREA OF FIRE-BARS AND LENGTH OF PIPE HEATED. (HOOD.)

Area of Bars in square inches.	Lengths of Pipe in Feet, Heated.		
	4″ diam.	3″ diam.	2″ diam.
75	150	200	300
100	200	266	400
150	300	400	600
200	400	533	800
250	500	666	1,000
300	600	800	1,200
400	800	1,066	1,600
500	1,000	1,333	2,000

The consumption of fuel in proportion to the area of fire-grate surface, may vary somewhat with the rapidity of draught, but other things being equal, 10 to 11 lbs. of coal, per square foot, per hour, may be considered a fair quantity; from this it is calculated that the areas of bars to heat the respective lengths of pipe will be as given in Table XXX., p. 216.

In some hot-water boilers special fire-bars are formed of a series of tubes, and connected with the boiler; the object being to increase the heating surface. This may be effected to a small extent, but water-bars cannot influence the power of a boiler very materially, so far as heating surface is concerned, when we consider that, not only is cold air supposed to be continually passing over each side of the bars, but that for practical purposes (see p. 201) horizontal surfaces beneath the flame are not reckoned at all. At the same time, it must be conceded, that if water-bars are used, a higher column of water is necessarily provided; but care must be taken that the boiler is connected with the fire-bars, and that the return pipe is connected with the water-bars, not merely with the boiler, or this advantage will be lost. Again, water-bars will, undoubtedly, last very much longer than solid bars.

While the admission of air is of primary importance, the exit of air is of secondary, if not of equal, importance. The throat of the furnace should be made small in comparison with the amount of air to pass through. There are several rules for ascertaining the height and area of chimneys, but they all apply to shafts of greater power than those usually employed for hot-water boilers. Local circumstances will generally determine the height. The area may be from 14 to 20 square inches for about every 10 to 12 lbs. of coal consumed per hour.

A dead plate, which is really nothing more than rendering part of the grate-surface solid, is useful for keeping the heat away from the front of the furnace, as well as, in some boilers, attaining more perfect combustion, by placing the fuel, as it is fed into the furnace, first on the dead plate, and then, when well heated, pushing it on to the fire-bars.

Each form of boiler requires its own treatment in setting, and each boiler maker is usually willing to give details of the setting which is best adapted for his particular boiler. It may be remarked, however, that the setting should be constructed of materials which are bad conductors of heat. The interior of boiler-settings should be cased with fire-bricks. In usual cases ordinary bricks may used for chimneys, although the lower portion may be cased with fire-bricks if considered desirable. Mortar is generally preferable to Portland cement, as the latter does not stand the heat well. Soot doors should be so fixed that flues, &c., may be kept free from accumulation of soot.

Stoke-holes, furnaces, and boilers, should always be protected by an enclosed shed from rain and wind, or heat will be lost by radiation and convection, notwithstanding that the boiler may be set in a good heat-arresting material.

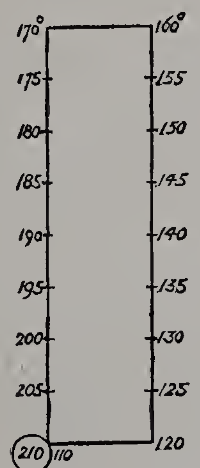
POSITION OF BOILERS.

The motive power of a boiler, as we have already seen (p. 191) is increased by adding to the vertical height of the column of water, therefore the lower the boiler below the pipes it has to heat, the better the apparatus will work. On the other hand we must not forget, that in a column of water, there is, for every foot of vertical height, a pressure at the base of that column of ·433 lb. per square inch. The thickness of the column of water, the shape of the containing pipe, its diameter, its absolute length, if it be inclined, twisted or inserted in the boiler in any position, make no difference whatever to the pressure. This is only proportionate to the vertical height. For instance ;—suppose we have a boiler, containing an internal area of 6 square feet, placed in the basement of a building ; 20 feet of 4-in. radiating pipes fixed 40 feet above it, and connected with it by a 1-in. flow and return, the total pressure on the boiler would be a little over 6 tons 13 cwts. (or 17·32 lbs. per square inch). If there were 200 feet of radiating pipes connected with it by a 4-in. flow and return, provided the vertical height remained the same, the internal pressure on the boiler would still remain precisely the same, viz. :—17·32 lbs. per square inch, or a total pressure of a little over 6 tons 13 cwts. We therefore see that it is of importance to determine a limit to the depth a boiler is fixed under the work it has to do. To connect a higher column of water to a boiler than it would resist, would not, however, cause it to explode ; it would only crack, as water contracts very little in bulk under pressure, consequently has very little alteration of bulk to sustain when the pressure is removed or the resistance to the pressure overcome.

In some cases, in consequence of defective drainage or other circumstances, the stoke-hole requires to be very shallow. When this is so, the minimum depth at which we may safely fix the boiler can easily be calculated from the data given on pp. 187-191, always remembering that the greater difference we may determine between the out-going and in-coming water, the shorter need be the vertical column, and the nearer (vertically) the boiler may be placed to its work.

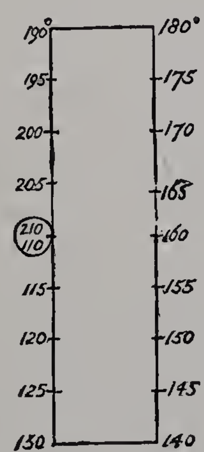
It is not advisable that pipes should dip below the boiler. Wherever it is placed, the boiler should certainly be at the lowest point.

Mr. Box shows this very clearly in the following manner. Fig. 108 shows the boiler placed at the lowest point, Fig. 108A the boiler fixed midway between the lowest and highest points.



Means 190° 140°

FIG. 108.



Means 160° 160°

FIG. 108A.

Vertical diagrams showing temperature of water in pipes with boiler in different positions.

In each case the water leaves the boiler at 210° and returns at 110°, but in the first case it will be noticed that the mean temperature of one column is 190°, that of the other 140°. So that the motive power for circulation will be the difference in the specific gravities of the two columns. In Fig.

108A each column has a mean temperature of 160°, consequently no circulation can possibly take place.

It may be possible to heat pipes and produce circulation when the boiler is absolutely above them, by the use of lofty vertical columns of water. In such a case, ascertain the height of columns which will be convenient; determine the temperatures at which the water enters and leaves the boiler; then make a plan of the pipes; accurately mark off, in the same manner as in Figs. 108 and 108A, the temperature at various positions along the whole line of pipes. Find the means of the ascending and descending columns, and it will be at once seen what motive power exists for disposal. In calculating the mean of the two columns, of course only those temperatures are to be added together which are found on vertical pipes; the temperatures marked on horizontal pipes must not be taken.

The boiler may also be fixed above its work by employing a circulating cistern, but this is not an advantageous method. In all cases, where it can by any possibility be done, the boiler should be below its work.

So far as regards the horizontal position of the boiler in relation to its work, this will generally be determined by local conditions. If a range of consecutive lean-to houses require to be heated, it is generally advisable to place the boiler in the centre of the range, behind the back wall, and to supply heat in both directions. (See p. 196.) Where this cannot be done, it may very well be placed at the end of a range, as the absolute necessity does not exist for the boiler to be near the house which requires the most heat, nor in fact near its work at all, as these points are determined by the area of radiating surface and the protection to mains between the boiler and its work.

Other things bring equal, a boiler should be placed where it can be conveniently stoked and fed; where a chimney can be easily provided for it; where it will be least unsightly; and where the stoke-hole can easily be drained, and as near as possible to its work.

FUEL.

Combustion is chemical combination usually attended with the evolution of light and heat. In the ordinary fuels, the carbon combines with the oxygen of the atmosphere to form carbonic acid, and the hydrogen combines in the same way to form water. When oxygen exists in a combustible containing hydrogen, eight parts by weight of the former combine with one of the latter, and water is formed, but no available heat is given out. Any excess of hydrogen not required by the oxygen which happens to exist in such a combustible, is, of course, available for heat. From experiments of Péclet, Playfair, De la Beche, &c., we find the chemical composition of ordinary combustibles to be as shown in the following table:—

Table XXXI.—Analyses of various fuels.

——	Carbon.	Hydrogen	Oxygen.	Nitrogen and Sulphur.	Water.	Ashes.	Total.
Coal, mean 97 kinds ...	·804	·0519	·0787	·0246	...	·0408	1·000
Coke...	·850	...	...	...	...	·150	1·000
Wood, dry ...	·510	·053	·417	...	...	·020	1·000
,, ordinary state	·408	·042	·334	...	·200	·016	1·000
,, charcoal ...	·930	...	...	...	...	·070	1·000
Peat, dry	·580	·060	·310	...	...	·050	1·000
,, ordinary state	·464	·048	·248	...	·200	·040	1·000

By Dulong's experiments, we find that when carbon combines with oxygen, and hydrogen combines with oxygen, in the proper atomic proportions, by combustion, the former evolves 12,906 units of heat per pound of carbon and the latter 62,535 units of heat per pound of hydrogen.

(A "unit of heat" is the amount of heat required to raise the temperature of a pound of water at 32°, one degree Fahrenheit.)

From the above data we are able to easily construct a table of the units of heat given by the foregoing combustibles, thus:—To take a pound of coal:—

		Units.
Carbon	$·804 \times 12{,}906 =$	10,376
Hydrogen	$·0519 - \frac{·0787}{8} = ·04206 \times 62{,}535 =$	2,630
		13,006

Table XXXII. shows the maximum comparative heating power of the various fuels. In practice Mr. Box considers that, taking coal for instance :—

5 per cent. would be lost in ashes, left unburnt,
20 per cent. would be lost by air in chimney,
12 per cent. would be lost by radiation in boiler-house,

TABLE XXXII.—UNITS OF HEAT EVOLVED FROM VARIOUS FUELS.

Fuels.	Units of Heat Evolved from the Combustion of a Pound of the respective Fuels.
Coal, mean 97 kinds... ...	13006
Coke	10970
Wood, dry...	6582
,, ordinary state ...	5265
,, Charcoal	12000
Peat, dry	8736
,, ordinary state	7151

leaving 63 per cent. available for heating. When a combustible contains water, not only is the effective weight of combustible matter reduced, but heat in the actual combustible matter is wasted in evaporating the water. Thus, wood, in an ordinary state, contains 20 per cent. of water, so that the combustible matter is reduced to 80 per cent., and this again is reduced to about 76 per cent. by 4 per cent. being required for the evaporation of the 20 per cent. of water.

In the first lines of this section the statement is made that the oxygen of the atmosphere is the supporter of combustion; but further remarks on the supply of atmospheric air to fuels will be found in the section, "Furnaces and Boiler-settings," p. 212.

Deduced from experiments by Rumford and others, Mr. Hood gives the accompanying table showing the quantities of coal consumed per hour in heating 100 feet of 4-inch pipe for various degrees of temperature of pipe and air.

The usual rate of combustion of coal is about 10 to 11 lbs. per square foot of fire-grate per hour.

All is not done, however, when we have ascertained which fuel will produce the greatest number of units of heat. Taking this as our only basis, we find by Table XXXII. that coal and charcoal are both superior to coke, but in practice it is frequently found that coke is the combustible best adapted for hot-water heating.

TABLE XXXIII.—CONSUMPTION OF COAL.

Diameter of Pipe.	Difference of Temperature between the Pipe and the Air, in the Building, in Degrees Fahrenheit.							
	150	145	140	130	135	125	120	115
inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4	4·7	4·5	4·4	4·2	4·1	3·9	3·7	3·6

Diameter of Pipe.	Difference of Temperature between the Pipe and the Air, in the Building, in Degrees Fahrenheit.						
	110	105	100	95	90	85	80
inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4	3·4	3·2	3·1	2·9	2·8	2·6	2·5

Cost must also enter into our calculations. Some boilers will consume equally coal, coke or wood; others, while they can consume coal are rendered much more efficient by being fed with coke. Much depends upon whether the boiler setting is formed of a good or bad heat-arresting material. Coal under some conditions is apt to distill rather than consume, when heat is lost and the bars choked. Coal gives a deposit of soot, and nothing can tend in a greater degree to the escape of heat by the chimney than coating the inside of boiler, &c., with such an excellent non-conductor as soot. Coke is not open to this objection. Smoke pouring from the chimney of a heating apparatus in a gentleman's grounds is not a very sightly object. Of course if perfect combustion took place, there would be no deposit of soot and no smoke; but perfect combustion is not yet attained by makers of hot-water boilers and furnaces. Until it is, coal must usually give way to coke.

We will just glance at the merits of the "lime-kiln system" of heating. Carbonate of lime (limestone) may be termed the fuel. This is mixed with coal and heated in a kiln, when the carbonic acid passes off at a red heat and lime is left behind. The heat evolved which would otherwise pass into the atmosphere, is utilized to drive a hot-water apparatus. It is true that from such a point of view, the heat may be said to cost nothing, but the system is really only suitable for very large establishments, and where such a commercial enterprise as lime burning is considered advantageous. There are not many noblemen or gentlemen, who, having no limestone on their estate, or not being in any way connected with the manufacture of lime, would care to purchase limestone, have it carted to their estate, set up a lime factory on the spot, and sell the manufactured article afterwards: all for the sake of saving a comparatively small sum per annum in coal or coke.

Both wood and turf have low heating power, but when converted into charcoal their power is more than doubled. Up to the present, however neither wood, turf, nor its products have found general favour as fuel.

Various artificial fuels have been invented, of which the principal, ingredients used are coal dust, refuse coal, coke, peat, bark, tan, sawdust, vegetable fibre, pitch, tar, &c. The latter two generally serving as the adhesive vehicles. A great disadvantage in connection with all these fuels, is that these adhesive materials, like coal, are apt to distill without being consumed; when combustion is checked, heat wasted, fire-bars fouled, and admission of air impeded.

Carburetted hydrogen or ordinary coal gas is sometimes used as fuel for a hot-water apparatus. This fuel has one advantage. It requires no attention; when once lighted it will burn for any length of time; and can of course be moderated at pleasure. Against this, the cost of burning it, in comparison with coke, is from five (with the most perfect practical combustion) to twelve times (when the combustion is imperfect and a great portion of the heat is unutilized). The products of combustion of coal gas are most deleterious in their effect on plants, and (unless a gas-stove be thoroughly isolated from the green-house) it is difficult to prevent them seriously injuring the contents. Notwithstanding this, very small apparatus are frequently driven by gas-stoves. For any more than a short length of radiating pipe, gas, as fuel, may be considered impracticable.

STOKING.

A boiler may be the best adapted for the purpose; the boiler-setting may be everything that is desired; the pipes may be properly fixed and contain the correct quantity of heating surface; the whole apparatus may be in the most thorough working order; yet it remains with the person who has charge of the apparatus whether success or failure attend its working. His duties are numerous and important, and we will mention some of them.

It is often left to the stoker to determine what fuel shall be used. His choice will depend upon the description of fuel which can be easily obtained, and its price in the locality; whether any refuse fuel on the estate, which would otherwise be thrown away, can be utilized; the particular form of boiler employed; and the work it has to do.

In feeding the furnace he must remember that great frequency in charging means increased consumption of fuel; and that long intervals between feeding generally means economy of fuel. He must use great discretion in this matter, however, as firing at long intervals is only economically possible with large furnace space. He must also exercise judgment in the thickness of fuel over the furnace bars. This again will depend upon the form of boiler. He must not forget to use the dead-plate when he can, for heating some of the fresh fuel before it is raked on to the bars. As a rule, the thinner and brighter the fire, the less chance of the formation of carbonic oxide, and the consequent loss of heat.

The manipulation of the damper and furnace doors must be determined in conjunction with and depend upon the amount of fuel and frequency of charge. These duties will generally test the efficiency of a stoker. Experience is really the only guide on these points, but it may be as well to remember that the damper should always be as much closed as is consistent with maintaining combustion; that a thick fire sometimes necessitates the admission of air above the fire-bars; that the admission and exit of too much air means rapid combustion, increased velocity of draught, and waste of heat up the chimney; and that admission of too little air with the exit of too much, means formation of carbonic oxide.

The stoker should see that his air-pipes and valves are in working order, and that neither they nor any other part of the apparatus is choked up with dirt, &c.; that the bottom of the supply cistern is always covered with water; that the water used for the purpose is clean rain-water; and that the boiler, fire-bars, flues, and chimney, are kept free from clinkers, soot, &c.

WATER SUPPLY.

THIS very wide subject, which can only be suggestively treated here, is naturally divided into two parts, the supply of soft, and the supply of hard water. The first has more connection with horticulture than the last, but as the gardener is frequently required to include the latter within his jurisdiction, a few words regarding both may not be out of place.

SOFT-WATER SUPPLY.

Whether for watering in the open garden, in horticultural buildings, for supplying the boiler, or for vaporizing purposes, the superior merits of soft or "rain" water over hard or "earth" water are well known. The rainfall in England varies considerably in different localities, from 20 to 70 inches per annum. In one spot in Cumberland as much as 135 inches have been known to fall in a year. But if we take an average of about 30 inches, and if we estimate the available rainfall upon roofs in England at 18 inches per annum, we cannot be far wrong. (See "Meteorological," p. 246.) For there is a direct percentage of loss, by capillary attraction under the laps; when the rain descends at a steeper angle than the inclination of the roof; and when absorption and evaporation take place. So far as horticulture is concerned, it is from the roofs of buildings that we require to obtain our soft-water supply. To provide against the contingency of long-continued fine weather, it is prudent to arrange for the collection of at least three months' rain water from such roofs.

STORAGE.

After the roofs have caught the rain which descends upon them, its storage is usually effected in various ways, dependent upon the size of the establishment and the inclination of the person under whose control it is effected. A tub, a barrel, a zinc or lead-lined wood cistern, a galvanized iron tank, a tank built of brick-work in cement, or a well, form some of the receptacles of storage. For general purposes, however, when the establishment is anything beyond a very small one, nothing can be better than a concrete tank. For more than 10,000 gallons, the strongest, cheapest and most serviceable tank which can be built is a circular one, in section the shape of half an egg, made of well-rammed concrete, and having a concrete dome top. If the top cannot conveniently be made in one dome, it may be supported by an iron pillar in the centre with a continuous arch springing from this pillar to the circumference. Such a tank is of the best form for resisting all lateral thrusts and is far preferable to large rectangular tanks, which not only have to be strutted by transverse walls, &c., but are continually liable to leakage at the angles and corners. Soft water should be protected from dust, frost, and the sun's rays, or vegetation will ensue, but the tanks containing it should always be ventilated and provided with a manhole for cleaning. It is most essential that water required for the interior of horticultural buildings should, at any rate for a certain time before use, be stored in tanks placed in a convenient position inside the buildings, in order that the water may approximate to the temperature of the atmosphere of the house. The tanks for this purpose may be of cement, concrete, or galvanized iron, covered by a wooden lid, and may be fed direct from a down pipe, or, if this be impracticable, pumped from the general storage tank. In the former case care must be taken to provide an overflow pipe, or a heavy storm may unexpectedly swamp the interior of the house.

In determining the size of tanks, the following data may be useful. The imperial gallon contains 10 lbs. distilled water at 62° Fahr. A cubic foot contains 6·24 (say $6\frac{1}{4}$) gallons, and weighs 62·425 lbs. Based upon the average rainfall, previously mentioned, a span green-house 100 feet long and 15 feet wide, will collect about 2250 cubic feet of water per annum. To provide for three months' supply, the storage tank should, therefore, not contain less than 560 cubic feet, or about 3500 gallons.

DISTRIBUTION.

The water may be either baled out (in the case of small tanks and inside green-houses) or pumped out as required (if the tanks are too large or inaccessible for baling). Or in large establishments, the spare time of a labourer may be utilized in pumping from the storage to distributing tanks situated above the ground level. With such an arrangement, pipes from the latter tanks, terminating in stand pipes and stop valves, may be laid on to various parts of the garden, which can thus be watered by a hose or watering pots, at any time required, without waiting for pumping or baling. A modification of such an arrangement is very essential in order that a constant supply of soft water may be provided in the boiler-house. A tap and not a self-acting ball valve should be used for feeding the expansion cistern of heating apparatus (see p. 193). Distributing tanks above ground may be constructed of slate, cast or wrought-iron. The latter material, galvanized, is best if the tank be of a moderate size. If very large, a tank constructed of cast-iron plates, flanged and bolted on the inside, is best. Either wrought or cast-iron tanks, above a small size, should be stayed with internal iron tie-bolts.

The metal pipes used, whether as connections between tanks, as distributing, as stand, or as supply-pipes should be protected from frost. If, from any reason, this is impracticable for the whole of the pipes, they should be so arranged that those pipes exposed could be emptied of their contents in frosty weather. A plan occasionally adopted for preventing the bursting, by frost, of a small section of exposed pipe always containing water, is to cut away a few inches of the pipe and substitute a piece of india-rubber tube. An elastic section of pipe is thus introduced for the expansion of the water in freezing.

Another mode of obviating the bursting of an exposed section of water-pipe by frost, is to place inside the pipe, at the part most liable to freeze, a small empty india-rubber tube, hermetically sealed at both ends. Tightly closed casks, cisterns, tanks, &c., containing water, may often be prevented from bursting, in consequence of the freezing of their contents, by floating in them, neck downwards, an empty champagne bottle or two. The india-rubber tube in the one case, and the bottles in the other case, contain an elastic cushion of air, which, by contraction, compensates for the expansion of the water. For a description of high-pressure tight, full straight way draw-off valves suited for stand pipes, see p. 198.

HARD WATER.

Ancient houses were generally built in valleys, not only in order that they might have protection from wind, but that they might be near streams. More accurately fitting doors and windows, improved means of heating, and increased facilities for raising water, have enabled modern dwelling-houses to be built on elevated ground. On many country estates, an important point for consideration is the supply of hard water for drinking, domestic, or farm purposes; and as the work of a gardener or bailiff would usually be limited to the means for conveying this water from a well, pond, stream, or spring, only the questions of raising and pumping hard water will be discussed here.

METHODS OF RAISING WATER.

The first question that arises is "What is the cheapest and most trustworthy means of raising the water?" We have the choice, according to the quantity required, the height to which it must be raised, and other local conditions, of using a pump worked by, 1st, A lad or man; 2nd, A pony or horse; 3rd, A hydraulic ram (which will raise either part of the same water which is used for power; or, by a diaphragm arrangement, clean water, when dirty water from another neighbouring source furnishes the power) a turbine, or water-wheel, in situations where a fall of water is available within reasonable distance at all seasons of the year; 4th, A windmill, where the situation is exposed, and where such a motor would not be considered unsightly ; 5th, A steam, a gas, or a Ryder's Hot-Air Engine, where none of the previous motors are suitable. To bring these various powers into comparison we must reduce them all to some general standard.

STANDARD OF POWER.

Engineers denominate the act of raising one pound weight of any substance through a distance of one foot vertical height, "one foot-pound," and this forms the usual "unit of work." Watt's old standard of one-horse power is equal to performing 33,000 of such foot-pounds in one minute. He fixed on this as he calculated that an English draught horse could do this amount of work for nine hours consecutively, when working a horse-wheel or similar contrivance.

MANUAL OR HORSE POWER.

Watt was mistaken in his estimate, however, for subsequent experiments have proved that, if kept in a fair condition, a horse can only perform about $\frac{2}{3}$rds of this, or about 22,000 foot-pounds per minute. A pony can do about 11,000 ; a donkey, about 4,000 ; and a man about 3,000.

Only about $\frac{3}{4}$ of the power expended in working a good pump is traceable in the result obtained, the remainder being lost by friction, slip of water past valves, &c. Now, to ascertain how many gallons per minute can be pumped into a tank by any of the above powers, we must divide these foot-pounds by 10 (the number of pounds in a gallon of water) multiply by the difference of level in feet between the source of supply and delivery tank, and take $\frac{3}{4}$ of the result.

Conversely, to calculate the foot-pounds which are necessary to produce a given result, we must multiply the number of gallons to raise per minute by 10, then by the difference of level in feet between source and delivery, and add $\frac{1}{3}$ of the result to compensate for loss of power by friction, &c., of pump.

WATER POWER.

If a fall of water be made available as power, we must first gauge the supply passing in gallons per minute (see "Instructions," p. 233). Multiply this number of gallons by 10, then by the available fall in feet. This will give the foot-pounds of power per minute available for driving either a hydraulic ram, a turbine, or a water-wheel. In the case of the first-named motor (which is the cheapest and most suitable for supplies up to 5 gallons a minute, and for height up to 150 feet, if a fall of 3 feet or upwards be available) to ascertain the number of gallons per minute which can be raised; take the foot-pounds of power available, divide by 10, and again by the difference of level in feet between supply and delivery, and then take half the result to compensate for loss of power in working the ram.

In the case of a turbine or water-wheel, the same calculations will apply, with the exception of deducting ·25 instead of ·5 for loss of power in working; as either of these motors are more economical of power than the hydraulic ram. A turbine or water-wheel is suitable for supplies above 5 gallons a minute, and where the height of the delivery above supply exceeds 150 feet. A turbine is in most cases rather cheaper to put down than a water-wheel; local conditions, however, will generally determine which is most suitable.

WIND POWER.

To determine the foot-pounds of power is not quite so simple a calculation with wind as with water. First find the velocity of the wind in feet per second by an anemometer (see "Meteorological," p. 246) or in the absence of this instrument, by watching the distance which a feather or morsel of thistledown will fly with the wind in a given time. Then cube this, multiply by the area of the sails of the windmill in square feet, and divide by 33. The result will be the foot-pounds per minute. Then to ascertain the quantity of water which may be pumped, proceed as directed in *Water Power*, thus:—Suppose the velocity of wind is 10 feet per second, and the area of each of the 4 sails, 40 square feet.

Then $10^3 \times 40 \times 4 = 160{,}000 \div 33 = 4{,}848$ foot-pounds, Now, supposing that the difference of level between source and supply is 100 feet. Then 4,848 ÷ 100 = 48. Take $\frac{2}{3}$ of this (remainder being lost by friction, &c., in windmill) and we have 32 lbs., or 3·2 gallons of water pumped per minute, 192 per hour, or 4,600 per day of 24 hours.

GAUGING A STREAM OR BROOK.

When a stream or brook is utilized as motive power, it is necessary to ascertain the quantity of water falling in a given time. This may sometimes be done by catching the water in a bucket of known capacity and noting the time required to fill it. The most generally useful method is, however, by a notch or weir. The following description of this mode is given by Mr. Charles L. Hett, of Brigg:—

The apparatus required is a piece of half-inch deal, Fig. 109, of sufficient length to span the brook, having a **V** notch cut in it, the angle of which must be 90°. The edge must be chamfered. A convenient depth for the notch is 5 inches. This allows about 107 gallons to flow per minute. A peg, Fig. 110, having a step cut in it the exact vertical height of the notch, and a rule divided into inches and tenths, complete the apparatus.

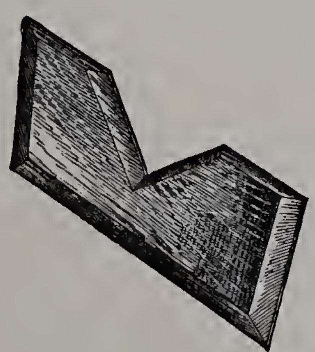


FIG. 109.—Notchboard for gauging a stream.

FIG. 110.—Levelling peg for notchboard.

After choosing the site for the dam, with a sharp spade cut grooves in each bank, and press the board down firmly in the grooves, so as to entirely stop the water, pressing soft clay around if necessary. Now measure the height from the surface of the water to the top of the board at each end and press down the highest end until it is quite level. When the rising water approaches the bottom of the notch, fix the peg into the bed of the brook at a distance of about 3 feet from the weir, and, at the moment the water rises to the bottom of the notch, drive the peg down until the step is exactly level with the surface of the water, and therefore level with the notch. The water will now begin to flow through the notch and will rise to a height that corresponds with the supply; so that by ascertaining the depth of water running over the notch the quantity may be deduced. This required depth is now to be measured in inches and tenths, by putting the end of the rule on the step in the peg and carefully

TABLE XXXIV.—GAUGING A STREAM.

Quantities of water corresponding to a given height above the bottom of the notch.

Height in Inches.	Gallons per Minute.	Height in Inches.	Gallons per Minute.	Height in Inches.	Gallons per Minute.
1·0	1·90	2·4	16·98	3·8	53·57
1·1	2·42	2·5	18·81	3·9	57·17
1·2	3·00	2·6	20·75	4·0	60·90
1·3	3·67	2·7	22·80	4·1	64·78
1·4	4·41	2·8	24·97	4·2	68·80
1·5	5·24	2·9	27·26	4·3	72·97
1·6	6·16	3·0	29·67	4·4	77·29
1·7	7·17	3·1	32·20	4·5	81·75
1·8	8·27	3·2	34·87	4·6	86·37
1·9	9·47	3·3	37·65	4·7	91·14
2·0	10·76	3·4	40·57	4·8	96·08
2·1	12·16	3·5	43·61	4·9	101·15
2·2	13·66	3·6	46·80	5·0	106·39
2·3	15·27	3·7	50·12	—	—

noting the height of the surface of the water. The flow of gallons per minute corresponding with the height, will be found in Table XXXIV., p. 234. To shorten the length of time required for the operation, it is advisable to stop the notch with clay while the water is rising.

Care should be taken that the stream be dammed up by the weir sufficiently to reduce it nearly to the condition of a still pond, and also that the water should have a clear fall from surface to surface not less in height than double the depth it runs over the notch. Where great accuracy is required, the weir should be adjusted by means of a spirit level and the top of the peg made exactly level with the upper edge of the weir by means of the same instrument and a parallel straight edge. The weir may with advantage be faced with thin sheet iron, and the notch cut through it; that through the wood being made of larger dimensions, so as to reduce the friction of the water to a minimum.

METEOROLOGICAL.

THE state of the atmosphere, its temperature, and everything connected with it, as well as the instruments used in making observations upon it, are so important in the cultivation of plant life, that we will devote a small space to the subject of elementary meteorology.

The illustrations are taken from engravings kindly placed at the author's disposal by Messrs. Negretti and Zambra.

BAROMETER.

The weight of the atmosphere, as is well known, is constantly varying, and the height of a column of mercury which exactly counterbalances the pressure of the atmosphere is used as a measurer of the weight of the atmosphere. This column of mercury, called a barometer, is one of the most useful meteorological instruments to the gardener, and its reading when taken in conjunction with other atmospheric indications, is advantageous, in many instances, in forecasting approaching weather changes.

In carrying out a series of observations with the barometer, the height of the mercury in the tube is usually "corrected" to a temperature of 32° Fahr. and sea level.

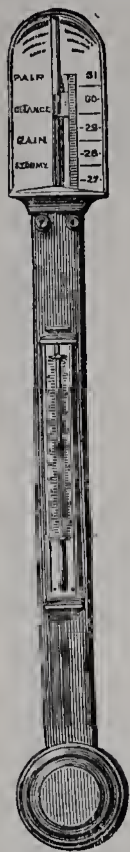


FIG. 111.—Barometer.

THERMOMETER.

The next most necessary meteorological instrument for the horticulturist is the thermometer, or temperature measurer. The thermometer is an in-

FIG. 112.—Thermometer.

strument in such common use, that a description of it is unnecessary; suffice it to say that the action of the mercurial thermometer depends upon the fact, that mercury increases in volume under the influence of heat to a much greater extent than glass. Spirit thermometers act on the

FIG. 113.—Hot-bed thermometer.

same principle. Thus, in the ordinary mercurial or spirit thermometer, we have an instrument which will tell us, not only what is the temperature of the atmosphere outside and inside our hot-houses, but also what is the temperature of our forcing-beds, of the soil in our gardens, of the hot-water pipes in our heating apparatus, &c. But to ascertain what is the temperature in the immediate vicinity of the thermometer, whenever we choose to look at it, is not always sufficient. We may require to know what has been the maximum or minimum temperature at any particular spot, during a given time, in our absence. For this purpose thermometers are constructed, in the tubes of which are needles, registering in one case the highest, and in the other case the lowest point which the column of mercury or spirit has reached. Usually separate thermometers are used for the maximum and minimum indications, as shown in Figs. 114 and 115.

FIG. 114.—Maximum thermometer.

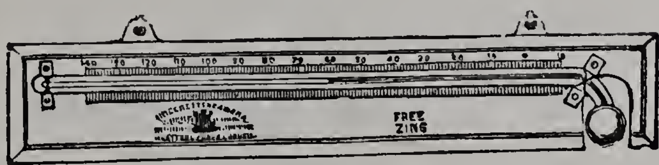


FIG. 115.—Minimum thermometer.

AIR TEMPERATURE.

It is usual to take the temperature of the air, uninfluenced by solar or any other radiation. For this purpose the thermometer is usually placed about 4 feet from the ground, in a position where it can be screened from the sun's rays as well as from radiation of heat or cold from any other body.

SOLAR RADIATION.

It is also useful to ascertain the heat received from the sun direct. To effect this, the thermometer having a blackened bulb, to absorb radiant heat, is enclosed in a glass vessel from which the air has been exhausted as much as practicable. (See Fig. 116.) The conductive and convective influence of the atmosphere is thus eliminated.

FIG. 116.—Solar radiation thermometer. Blackened bulb in vacuo.

HYGROMETER.

The atmosphere is capable of holding in invisible suspension a certain amount of moisture. The higher the temperature, the larger is the amount of this moisture. The rise in temperature and the increase in moisture do not, however, proceed in the same ratios. When the atmosphere holds its maximum amount of moisture invisibly, the "point of saturation" is reached. Beyond this point, the moisture condenses and becomes visible as dew, fog, mist, &c. (See "Condensation and Drip," p. 163.) The following (from Glaisher's Hygrometric Tables) will show temperatures Fahr. from 0° to 80° and the corresponding elastic force of vapour, indicated by the height of mercury it can support :—

TABLE XXXV.—ELASTIC FORCE OF VAPOUR.

Temp.	Force of Vapour.	Temp.	Force of Vapour.	Temp.	Force of Vapour.
°	inch.	°	inch.	°	inch.
0	·044	30	·167	60	·518
5	·054	35	·204	65	·617
10	·068	40	·247	70	·733
15	·086	45	·299	75	·868
20	·108	50	·361	80	1·023
25	·135	55	·433	—	—

We thus see that while air at a given temperature may easily hold in invisible suspension a certain quantity of aqueous vapour, if the temperature of such air be lowered, the point of saturation may soon be reached and condensation take place. Again, the temperature of air—already holding a certain amount of invisible moisture—may be raised, and so much additional moisture from extraneous sources taken up, that the slightest fall in the temperature will bring the air beyond the point of saturation.

Again, inasmuch as temperature and saturation do not, as shown by Table XXXV., proceed in the same ratios, it is quite possible for a body of air at one temperature to meet a body of air at another temperature, each

FIG. 117.—Hygrometer. Wet and dry bulbs.

body not fully saturated, and yet for the resultant contact to produce in the whole, condensation as well as complete saturation. When air, say not fully saturated, is brought in contact with air at the same temperature but holding a smaller quantity of moisture, the latter air has a tendency to take up some of the moisture contained in the former until an equilibrium is established. By the application of this principle it will be at once apparent how a damp apartment may be dried by passing through it a current of external air ; of course, it is of no use trying to dry an apartment in this way, if the external air be already fully saturated, or a difference between the temperatures of the external and internal air, would, upon contact, produce condensation. This principle and its application should be borne in mind, in ventilation of all kinds. (See "Ventilation," p. 131; "Fruit-Room," p. 78.)

TABLE XXXVI.—INDICATIONS OF THE HYGROMETER. (GLAISHER.)

Temperature of the Air.	Difference between Wet and Dry Bulbs in Degrees.											
	1	2	3	4	5	6	7	8	9	10	11	12
	Degrees of Humidity, Saturation being 100.											
32°	87	75	...	...	...	...	...	...	...	...	...	...
42°	92	85	78	72	66	60	54	49	44	40	36	33
52°	93	86	80	74	69	64	59	54	50	46	42	39
62°	94	88	82	77	72	67	62	58	54	50	47	44
72°	94	89	84	79	74	69	65	61	57	54	51	48
82°	95	90	85	80	76	72	68	64	60	57	54	51
92°	95	90	85	81	77	73	70	66	62	59	56	53

Temperature of the Air.	Difference between Wet and Dry Bulbs in Degrees.											
	13	14	15	16	17	18	19	20	21	22	23	24
	Degrees of Humidity, Saturation being 100.											
42°	30	27	...	...	...	...	...	...	...	...	...	...
52°	36	33	30	27	25	...	...	...	...	...	...	...
62°	41	38	35	32	30	28	26	24	...	...	...	...
72°	45	42	39	36	34	32	30	28	26	24	23	22
82°	48	45	42	40	38	35	33	31	29	27	26	25
92°	50	47	45	43	41	38	36	34	32	30	28	26

It is, therefore, frequently necessary to ascertain the comparative humidity of the atmosphere. This is effected by a hygrometer, or a combination of two thermometers (see Fig. 117, Hygrometer, Wet and Dry Bulbs), one of which has its bulb exposed to the atmosphere in the usual way, the other has its bulb covered with muslin, kept continually wet by a filament of thread leading to a small vessel of water. The effect of evaporation is to lower the temperature, so that the dryer the air, the greater will be the evaporation of the moisture on the wet bulb, and the lower will its temperature fall below that of the dry bulb; the greater the amount of moisture in the atmosphere, the slower will be the evaporation and the smaller will be the difference of temperature between the wet and dry bulbs.

The readings of the hygrometer taken in conjunction with Table XXXVI., will be found extremely useful in ascertaining the degree of humidity, not only of the external air, but of that in hot-houses of all descriptions. When the point of saturation is reached there would be no difference between the readings of the wet and dry bulbs. The dew point is the temperature at which the amount of moisture in the atmosphere suffices for saturation; so that to register the dew point by a thermometer placed on the grass is as effectual though not so convenient a method to determine the point of saturation as the wet bulb of the hygrometer.

ELECTRIC THERMOMETER AND ALARM.

It is extremely essential, in small estates, as in large and important combinations of glass houses, that a gardener have warning in case the temperature either rise above or fall below a certain point. During the daytime the personal attention of the gardener or his assistants obviates the necessity for extraneous warning; but during the night the temperature of the atmosphere may suddenly fall, a severe unexpected frost may occur, the fires may not have been properly banked, and the gardener may be very tired and fast asleep. A combination of these circumstances is liable to take place even with the best supervision, and the disastrous consequences which ensue are only known to the gardener, who, in a single night, sees the result of months, perhaps years, of past labour entirely destroyed. An extremely simple apparatus may, however, be employed to obviate all this, and to give an infallible warning to the gardener at any hour of the day or night, the moment the temperature in any house or houses falls below or rises above any point which he may choose to determine. It is an automatic electric maximum and minimum thermometer and alarm. The following will explain it:—

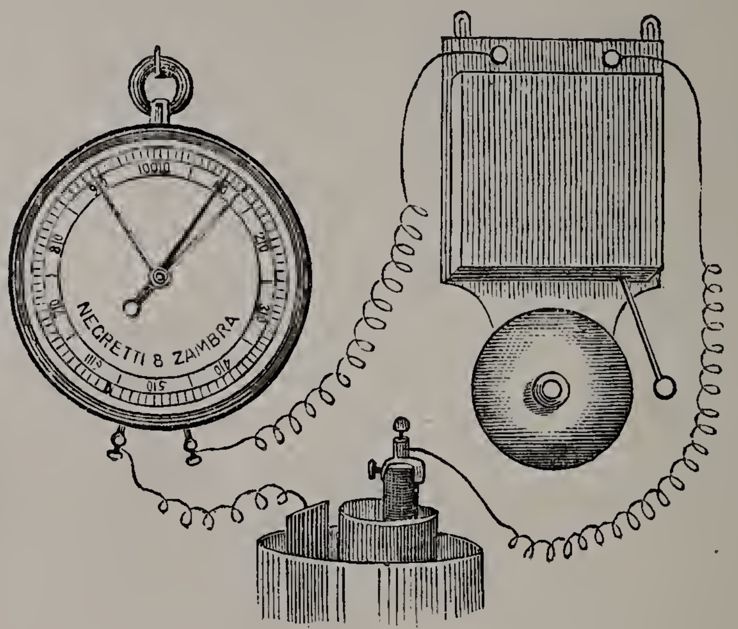


FIG. 118.—Electric thermometer and alarm.

Fig. 118 represents an apparatus of which the dial portion or electric thermometer is placed in the green-house, the temperature of which is required to neither rise above nor fall below certain limits. The bell may be placed in the gardener's bedroom, the battery in any convenient position. An insulated wire passes from one pole of the battery to one binding screw of the thermometer, another wire passes from the remaining binding screw of the thermometer to one side of the bell, while a wire joins the other side of the bell to the unoccupied pole of the battery. When the temperature in the vicinity of the thermometer rises above or falls below a certain pre-determined point, contact is established between the two ends of the wires at the thermometer, the electric circuit is completed, and the bell continues to ring, until the temperature returns to its previous limits or one of the wires is disconnected at some point. The gardener hearing the bell would at once take measures for raising (or lowering as the case may be) the temperature in the house containing the thermometer. Any number of thermometers, each registering required different maximum and minimum temperatures, may be used for different houses and all connected with the same battery and bell. The principle relied upon for the action of the above thermometer is the expansion and contraction of a metal coil by heat or cold. When such a coil, forming part of the galvanic circuit, expands or contracts beyond certain points, it makes connection with an adjustable platinum stud, completes the circuit and causes the bell to ring. This is a much more reliable and convenient form of apparatus than the electric mercurial thermometer, which cannot be easily made adjustable, is, by galvanic action, liable to oxidise and produce imperfect contact. The wires must be insulated; if above ground, by a coating of gutta-percha and cotton; if underground, by a thicker coating of gutta-percha, perhaps an outer casing of hemp, and a wood box or trench.

VANE.

The direction of the wind is another point to be observed, and in order to determine this accurately, care should be taken that the vane is as little as possible influenced by local or induced currents. It should easily swing with the wind, friction should be reduced to a minimum, and the resistance should be as much as possible on one side of the spindle. If the resistance were equal on both sides, the vane would not act at all (the same

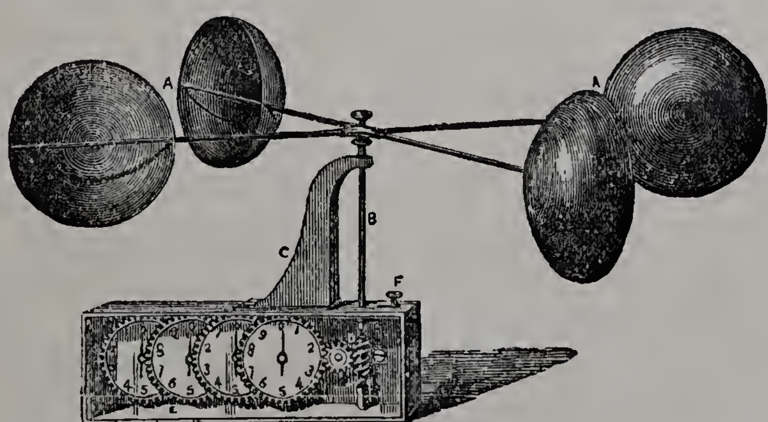


FIG. 119.—Anemometer.

principle applies as in throttle ventilators, see p. 142) but would be said to be in equilibrium.

ANEMOMETER.

It is often useful to determine the rapidity of the wind by this instrument (see Fig. 119) or in the absence of this, the pressure of the wind by a wind gauge.

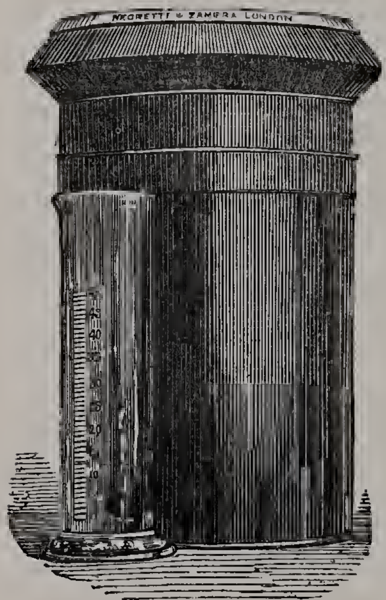


Fig. 120.—Glaisher's 8-inoh rain gauge.

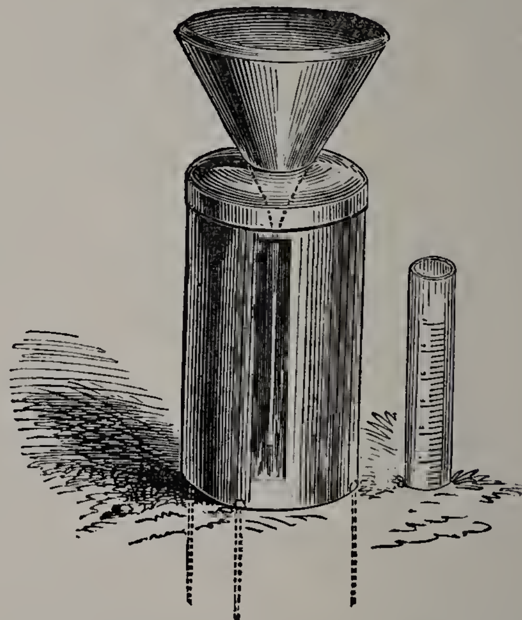


Fig. 121.—Negretti & Zambra's 5-inch rain gauge.

RAIN GAUGE.

The amount of rain falling is easily measured by means of a funnel-top rain gauge and a glass measure graduated to hundredths of an inch. As mentioned in "Water Supply," (p. 227), rainfall varies in England from 20 to 70 inches per annum, but the average may fairly be taken as 30 inches, and the available rainfall gathered from roofs as about 18 inches per annum. The barometric height and the rainfall are measured by inches; the thermometers by degrees and all parts of inches or degrees by decimal notation.

In England the thermometric scale used is that determined by Fahrenheit, in which freezing point is marked 32°, and boiling point 112°, and the parts between the two equally divided; in other countries two other scales are in use, viz., those of Centigrade (freezing point zero, boiling point 100°) and Reaumur (freezing point zero; boiling point 80°), as shown by Fig. 122, p. 248.

The following table of velocity and pressure of wind may be interesting:—

TABLE XXXVII.—WIND VELOCITY AND PRESSURE. (MOLESWORTH.)

Miles per Hour.	Feet per Minute.	Feet per Second.	Force in lbs. per Square Foot.	Description.
1	88	1·47	·005	Hardly perceptible.
2	176	2·93	·020	Just perceptible.
3	264	4·4	·044	
4	352	5·87	·079	Gentle breeze.
5	440	7·33	·123	
10	880	14·67	·492	Pleasant breeze.
15	1320	22·0	1·107	
20	1760	29·3	1·968	Brisk gale.
25	2200	36·6	3·075	
30	2640	44·0	4·428	High wind.
35	3080	51·3	6·027	
40	3520	58·6	7·872	Very high wind.
45	3960	66·0	9·963	
50	4400	73·3	12·300	Storm.
60	5280	88·0	17·712	Great storm.
70	6160	102·7	24·108	
80	7040	117·3	31·488	Hurricane.
100	8800	146·6	49·200	

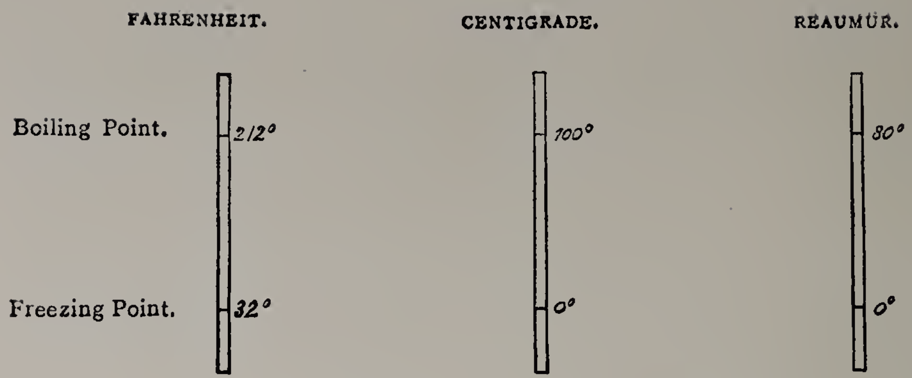


FIG. 122.—Thermometric scales.

The following is a suggestive skeleton table of meteorological observations for one week, taken from the *Journal of Horticulture*. Other columns may, of course, be added where temperatures are required to be taken of various positions in hot-houses, &c. :—

TABLE XXXVIII.—METEOROLOGICAL OBSERVATIONS.

DATE.	9 A.M.					IN THE DAY.				Rain.
	Barometer at 32° and Sea Level.	Hygrometer.		Direction of Wind.	Temp. of Soil at 1 foot.	Shade Temperature.		Radiation Temperature.		
		Dry.	Wet.			Max.	Min.	In Sun.	On Grass.	
	ins.	deg.	deg.		deg.	deg.	deg.	deg.	deg.	ins.
Sunday										
Monday										
Tuesday										
Wednesday										
Thursday										
Friday										
Saturday										
Means.										

REMARKS.

LEGAL.

THERE are several points of law and expediency which frequently require to be decided regarding horticultural buildings.

TENANT'S FIXTURES.

So far as nurserymen, market-gardeners, and others, who build green-houses for the purpose of trade, are concerned, the law is clear. Such structures erected by a tenant are removable by him at any time during his tenancy. To persons who do not erect green-houses for the purposes of trade, the law says: "What is attached to the freehold becomes part "of it;" and also, "Green-houses built in a garden and constructed of glass "and wood-work, united by mortar to a brick foundation, are not removable "by the tenant who erects them." A nurseryman or market-gardener may also remove small trees or shrubs, but unless required for the purposes of trade, nothing whatever may be removed.

So far the law is very explicit. But there arises the question of tenants, who wish, for instance, to build a small green-house against their dwelling, or on or against their garden-wall, in such a manner that they may have the legal right to remove it at the end of their tenancy. They see they must not put it on an ordinary brick foundation, neither must they attach it to the freehold, yet they will find almost any builder willing to erect their green-house for them, and persuade them that they possess a tenant's fixture, by telling them that "no mortar exists between the brick foundation and the wood-plate resting upon it," and "that the structure is not attached to the freehold, as it is only secured to the wall by temporary bolts and nuts." The end of the tenancy arrives, our tenants prepare to cart away their green-house, when the landlord steps forward, stands upon his dignity, and forbids them. The surprised tenants, conscious of their legal power, resolve to fight the landlord. The case comes into court. There are some hair-splitting arguments by the lawyers, and—the chances are against the tenants winning the day. From several cases which have come under the author's observation, a tenant, in his opinion, is never sure of having the absolute legal right of removing a green-house erected by him during his tenancy, unless he absolutely builds it on wheels and can drag it inside or out of his back gate whenever he chooses.

There is a solution, however, to what may appear in view of the above opinion, to be a legal hardship, and it is this:—Let the tenant, before he builds his green-house, obtain an undertaking from his landlord, that the latter will allow the structure to be removed at any time during the tenancy, upon the tenant leaving the freehold in the same condition as it was before building the green-house. Every one is satisfied and unnecessary and annoying litigation is prevented.

Boilers set in brick-work and pipes having rust or the usual cement joints, cannot be removed; but hot-water pipes having india-rubber or other removable joints, may be disconnected and removed from a boiler set in brick-work; or portable independent boilers used with jointed pipes, can be removed as tenant's fixtures.

PARTY WALLS, ETC.

If eaves or a gutter is constructed to project over a neighbour's land, the latter has the legal right to have them pulled down, without waiting for an actual inconvenience to arise, such as by water being discharged on to his land. Before proceeding to take this step, however, it is advisable to give notice to the proprietor in order that he may remove the offending projection. Twenty years' undisturbed existence of an over-hanging gutter or eaves, constitutes an acquired right to the easement. In the case of two adjoining tenants, if one or both of them wish to build a green-house against, upon, or above, a party (garden or other) wall, the consent and agreement of the respective landlords should, as a prudent precaution, be first obtained.

THE METROPOLITAN BUILDINGS ACT

For London and its neighbourhood.

Within this area, green-houses must be built in conformity with the above Act, which says in Schedule I.: "Every building shall be enclosed "with walls constructed of brick, stone, or other hard and incombustible "substances, and the foundation shall rest on the solid ground or upon "concrete or other solid sub-structure." In several cases, it has been decided that the words of the above schedule amount to a prohibition against building the walls of wood or other combustible substance. According, however, to Section 6: "Green-houses, so far as regards the "necessary wood-work of the sashes, doors, and frames," as also the entire building, "If distant at least 8 feet from the nearest street or alley, whether "public or private, and at least 30 feet from the nearest buildings and from "the ground of any adjoining owner," are exempt from the operations of the Act. Notice should in all cases be given to the district surveyor previous to building, and his fee, as regulated by the Act, paid.

The rules as to close fires and pipes for conveying vapour, &c., are contained in Section 21 of the Act, as follows:—

1. "The floor under every oven or stove used for the purpose of trade "or manufacture, and the floor around the same for a space of eighteen "inches, shall be formed of materials of an incombustible and non-conduct- "ing nature:

2. "No pipe for conveying smoke, heated air, steam, or hot water, shall "be fixed against any building on the face next to any street, alley, mews, or "public way:

3. "No pipe for conveying heated air or steam shall be fixed nearer than "six inches to any combustible material:

4. "No pipe for conveying hot water shall be placed nearer than three "inches to any combustible material :

5. "No pipe for conveying smoke or other products of combustion shall "be fixed nearer than nine inches to any combustible material :

"If any person fails in complying with the rules of this section he shall "for each offence incur a penalty not exceeding twenty pounds, to be "recovered before a justice of the peace."

THE FEES PAYABLE TO DISTRICT SURVEYORS ACCORDING TO SCHEDULE II. ARE :—

Fees for New Buildings.

	s.	d.
For every building not exceeding 400 square feet in area, and not more than 2 stories in height	30	0
For every additional story	5	0
* For every additional square of 100 feet or fraction of such square	2	6
* For every building not exceeding 400 square feet in area and of one story only in height	15	0

No fee shall exceed £10.

* These are the fees which usually apply to Horticultural Buildings.

LOCAL BOARDS, ETC.

In outlying and country districts the jurisdiction of Local and other Boards should not be ignored.

The scale of professional charges for architects, surveyors, &c., is, according to "Hurst," as follows :—

ARCHITECT'S RATE,

Including preliminary sketches and designs complete, survey of site, general drawings, specification and approximate estimate, workings, personal supervision and superintendence, exclusive of clerk of works, 5 per cent. on the value of work estimated.

Under this charge the architect is bound to provide one set of drawings, and one set of tracings, with duplicate specification; it being understood that the architect is paid for the use only of the drawings and specification, and that they remain his property at the completion of the work.

In addition to the above the following may be charged extra:—

Procuring and examining tenders for the work, ½ per cent.

Arranging with artists, tradesmen and others for sculpture, stained glass, and works of a similar class for which the architect does not furnish the design but to which he gives a general supervision, 2½ per cent.

Travelling and incidental expenses.

Measuring up works and certifying builder's accounts for extras and omissions, as per "Surveyor's Rates."

Special charges may be agreed upon for small or special works.

SURVEYOR'S RATE

For measuring works in small new buildings, and on repairs, including a bill of the particulars, 2½ per cent.

Estimating quantities from plans and specifications and preparing bills of quantities for small or difficult work, 2½ per cent.

For works of very small value the charge is by the day.

Large buildings in proportion to size and elaborateness.

Lithographing and travelling expenses extra.

INSURANCE.

IT is to be regretted that the heavy losses which horticulturists and others so frequently suffer by fire and hail, are not more often averted by the protection which a policy of insurance affords. It is singular, when a casualty such as a severe hail storm, occurs, to note how few of the sufferers have availed themselves of the advantages which insurance companies offer.

The following information, kindly supplied to the author by the Royal Farmer's Insurance Co. (a representative company) may be useful.

Green-houses and conservatories are insured against fire at the rate of 4s. 6d. per cent. per annum ; but policies upon their contents, such as plants, fruits, &c., are not granted, unless under special circumstances. Heating such structures by means of air or water passing through pipes—so long as the piping does not actually come in contact with any inflammable material, and the furnaces are outside—is not considered hazardous. Losses shown to have been caused by lightning, though no fire has been occasioned thereby, are allowed for.

Insurances can also be effected to cover losses by hail to glass, at the following rates :—

Sheet glass,	16 oz. per square foot and upwards,			20s. per cent.	
„	„ 13 oz.	„	„	30s.	„
Plate	„			40s.	„
Crown	„			42s.	„

To insure glass, the following particulars must be given :—

Description of glass. Description and size of each building for identification. Number of square feet of glass it contains. Situation of the buildings. Price per square foot of the glass, including the cost of re-glazing and painting the frames. Estimated value of the glass in each building. Unless the whole of the glass in a building is required to be insured, that part to be insured must be specified.